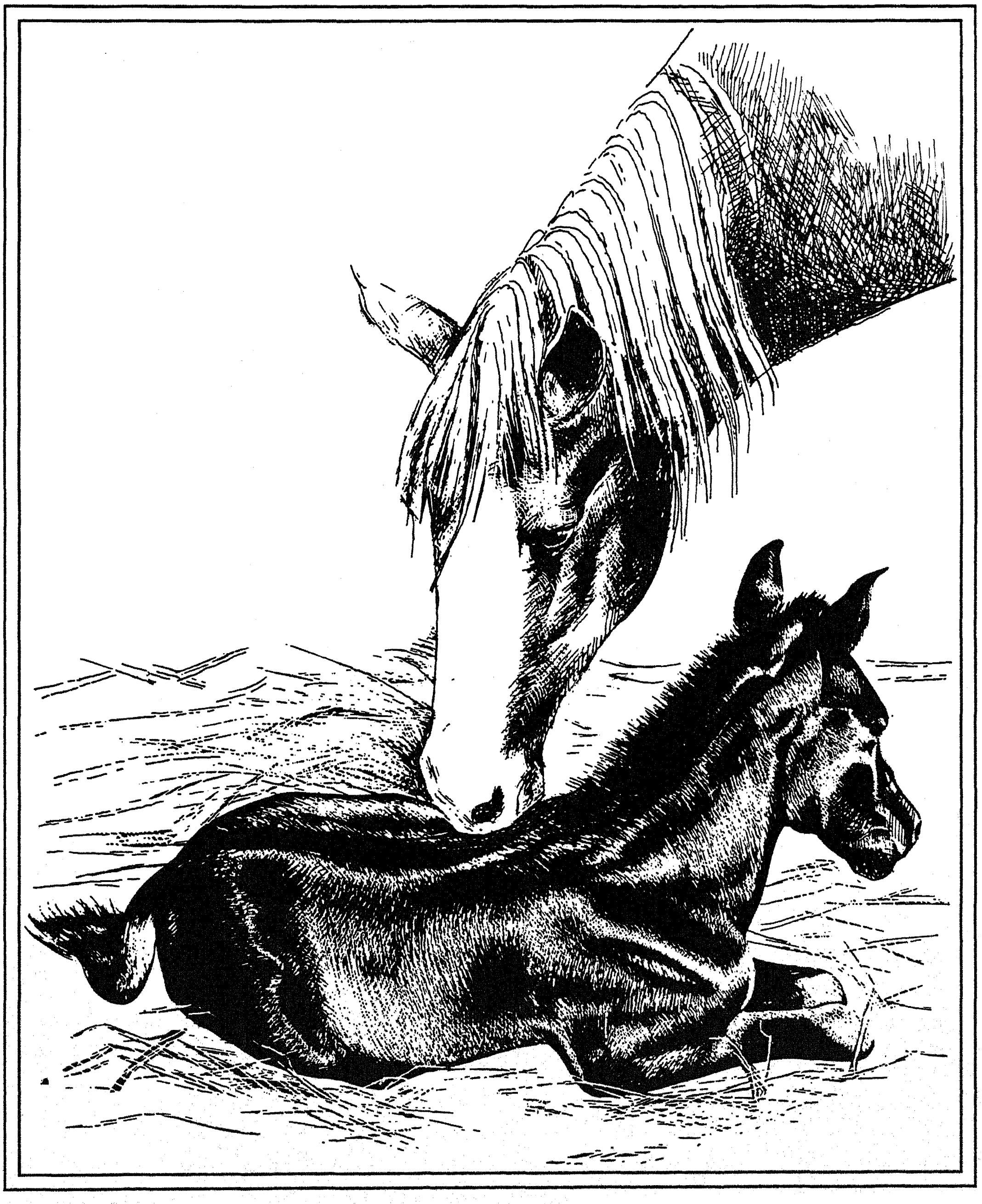
Extension Bulletin 797

EQUINE REPRODUCTION AND GENETICS



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The Ohio State University

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Picket, B. W., Voss, J. L., and Amann, R. P. *Management of the Stallion for Maximum Reproductive Efficiency.* Animal Reproductive Laboratory, Colorado State University, August 1981.

Figures 4 and 5 were redrawn from Figures 1 and 2-2 of the following reference:

Ginther, O. J. *Reproductive Biology of the Mare.* McNaughton and Gunn Incorporated. Ann Arbor, Michigan, 1979.

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EQUINE REPRODUCTION

The horse has had the reputation of being the least fertile of domesticated farm animals. This is not true. The cause of a national 55 percent foaling rate of all mares bred is not the horse but poor management. Horse farms using good breeding management procedures have had conception rates of 80 to 90 percent and foaling rates of at least 70 percent, which compares favorably with other farm animals. To gain these results, a thorough understanding of the reproductive processes involved in both the mare and stallion is essential.

THE MARE

ESTROUS CYCLE

A mare's normal estrous cycle is 21 to 22 days and can be divided into two parts. Estrus, commonly called "heat," is a period when the mare shows signs of desiring copulation with a stallion. Diestrus is the time when she does not show signs of sexual receptivity.

Although the estrous cycle begins at puberty (about 9 to 12 months of age), the filly should not be bred until she is at least three years old. This recommendation is based on allowing the filly to reach sufficient maturity to carry a foal to term. Although some fillies bred as 2 year olds have been able to carry a foal to term, several have conceived and later aborted due to insufficient development of the uterus.

The mare is a seasonally polyestrous animal. This means that she cycles many times in a year but has a season (winter) in which she fails to cycle. Failure to cycle is called anestrus and in the mare it is related to the length of daylight. As daylight increases, the mare begins to cycle. In late fall, as daylight decreases, she ceases to cycle. Prolonged temperatures below 0°F may also contribute to keeping the mare in anestrus.

With a January 1 universal birthdate for horses, the pressure is on breeders to produce foals born early in the year. As a result, breeders are trying to breed many mares when the animals are just starting to come out of the winter anestrus.

To deal with the complications of breeding mares, an understanding of the estrous cycle and its hormonal control is necessary. Hormones primarily regulating reproduction in the mare come from the anterior pituitary, posterior pituitary, ovaries (from the follicle and the corpus luteum), uterus, fetus and placenta. Following is a list of the hormones and their primary function by source.

ANTERIOR PITUITARY

FSH (follicle stimulating hormone) — The mare is born with nearly 100,000 oocytes. This hormone acts on about 10 oocytes each cycle to start them to develop into follicles. A follicle is a fluid-filled membrane containing the ovum (egg) and other specialized tissues (Figure 1).

LH (luteinizing hormone) — LH acts on the growing follicles started by FSH to mature some of them and cause at least one to ovulate (release of the egg from the ovary into the oviduct). After ovulation, LH is responsible for the formation of the corpus hemorrhagicum (named derived from its bloody appearance), which changes in a few days to a corpus luteum, also called a yellow body due to its color.

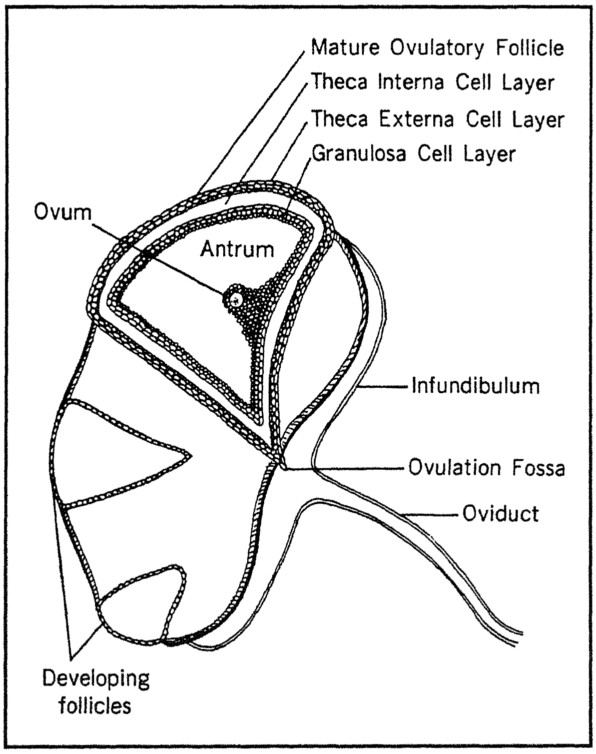


Figure 1. Ovary with related structures.

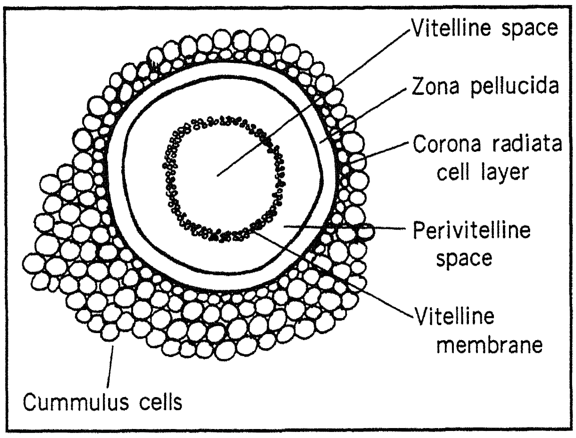


Figure 2. Released ovum.

Prolactin — This hormone is important in maintaining milk synthesis in the lactating mare. Its continual release is determined by milk removal from the udder. Prolactin is also involved with producing the mother instinct.

POSTERIOR PITUITARY

Oxytocin — Produced in specialized areas of the hypothalamus, oxytocin is stored and then released from the posterior pituitary. The hormone causes contractions of the uterus to aid the transport of sperm up the oviduct to the site of fertilization. Oxytocin later contracts the uterine muscles during labor to expel the foal.

A third function of oxytocin is to cause contraction of the muscle tissue in the udder to push milk down toward the teat for the nursing foal. Oxytocin is released as a result of the foal rubbing the udder or attempting to nurse. That is why an older foal often will shove and push against the udder before wanting to nurse and then wait 30 to 60 seconds until the hormone can cause milk letdown before trying to suckle.

OVARIAN

Estrogen — Estrogen is produced by the theca interna cells of the developing follicle. The functions of ovarian estrogen are as follows: development of secondary sex characteristics of the female, desire for copulation, thickening of the vaginal wall to withstand the stresses of copulation, mucous production to protect against infectious organisms introduced at time of breeding, growth of uterine tissues, growth and muscular activity of the oviducts, and sensitization of tissues to the effect of other hormones.

Inhibin — Inhibin is produced by the developing follicle and may act as a signal to stop further FSH release.

Progesterone — Progesterone is produced by the granulosa cells of the follicle, which after ovulation then forms much of the CL (corpus luteum). Progesterone produced in the follicle weakens the connective tissue surface of the follicle, allowing it to erupt and release the ova into the oviduct. CL progesterone causes the following: closing of the cervix, uterine secretions for nourishment of the embryo, placental growth, and prevention of uterine contractions and LH release.

UTERINE HORMONES

Prostaglandin — Prostaglandin is released by the uterus if no embryo is present and causes the CL to regress to a nonfunctional state. This allows a new cycle to begin because progesterone is no longer preventing LH release.

Relaxin — Relaxin probably is released by both the placenta and uterus to relax the pelvic ligaments and other structures around the birth canal. The effect of relaxin begins about 30 days before birth and is responsible for the sunken tail heads, elongation of the vulva and flabby appearance of the rear quarters.

FETAL HORMONES

The embryo migrates through the uterus from about the sixth day after ovulation until day 16. While migrating, the embryo secretes a substance to prevent prostaglandin release from the uterus so that the CL can continue to function. Research shows that if the embryo is not allowed to migrate, the CL is lysed, the embryo is lost and a new cycle begins.

PLACENTAL HORMONES

Estrogens — These are produced in large amounts in the pregnant mare and are important in the growth of the fetus, development of the mammary duct system and preparation of the uterus for giving birth.

Progesterone — Placental progesterone replaces CL progesterone by day 120 of gestation. Experiments in which ovaries were removed from mares 180 days pregnant revealed that pregnancy was maintained by the placental hormones. Functions of placental progesterone are to continue to prevent uterine contractions, develop the secretory tissue of the udder, prevent milk synthesis, prevent LH release and promote growth of the placenta.

PMSG (pregnant mare serum gonadotrophin) — PMSG is produced by the endometrial cups, which are made by the placenta starting about day 26 of gestation. Production of PMSG starts by day 40 and lasts until about day 120. The cups are then sloughed away. PMSG causes the development of accessory follicles that may or may not ovulate but will form accessory corpora lutea. Research has not substantiated the theory that these are necessary in maintaining pregnancy.

Reproductive cycle

An open cycle, one in which the mare does not conceive, has the following interaction of hormones. FSH is released and causes the formation of follicles. As they develop they release inhibin, which decreases FSH release. These partly developed follicles then come under the influence of LH (available now due to low progesterone levels), which will mature the follicle.

The growing follicle produces estrogen that causes estrus (heat) and protects the lining of the reproductive tract against injury or disease. The mature follicle then ovulates due to progesterone release from the granulosa cells of the follicle, weakening the follicle wall. LH is responsible for the formation of the CL, which begins to produce progesterone. The progesterone stops LH release, preventing any more follicles from maturing, decreases the amplitude and frequency of uterine contractions prevalent during heat, closes the cervix, and causes the uterus to produce uterine milk. Because no embryo is in the uterus by days 9 to 16, prostaglandin is produced by the uterus and acts on the CL to lyse it. After the CL is lysed and stops progesterone production, the pituitary can again release LH to mature new follicles.

A pregnant cycle would have the same sequence of events. However, with an embryo present in the uterus, no prostaglandin would be released due to secretions from the embryo being released while it migrates through the uterus. By days 16 to 17 the embryo ceases to migrate and usually will begin to attach to the uterus at the base of either horn.

By days 26 to 34 the developing placenta of the embryo starts forming endometrial cups. These are visible by day 40 and produce PMSG, causing accessory corpora lutea to form and to produce progesterone. PMSG production is highest during days 40 to 90 and decreases greatly by day 100. The endometrial cups are completely gone by day 160. By days 120 to 180 the placenta has taken over the production of progesterone and the CL of pregnancy disappears. The placental progesterone decreases the uterine contractions and develops the secretory tissue of the mammary gland but inhibits milk production. The placenta also produces estrogens, which aid in nutrient transfer from mare to fetus, develop the duct system of the udder and sensitize the uterus to oxytocin influence at time of parturition.

During the last month of pregnancy, the ratio of estrogen to progesterone changes as progesterone drops. The udder begins to enlarge and relaxin relaxes the pelvic ligaments and softens tissues around the birth canal. At some point oxytocin causes contraction of the uterus and the foal is born, followed

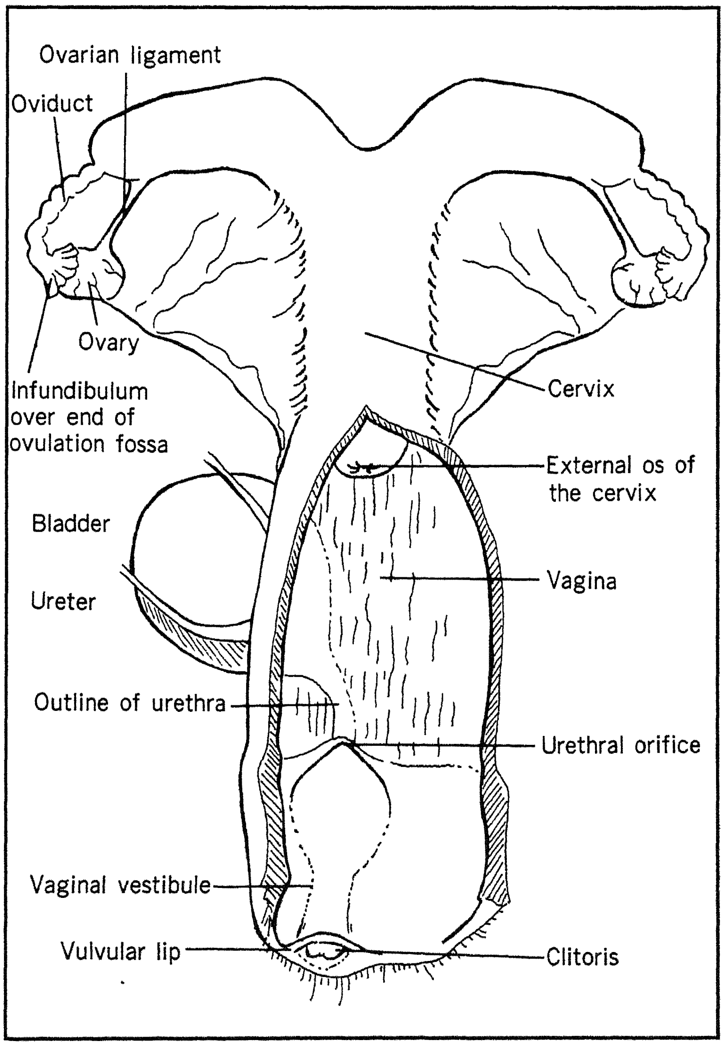


Figure 3. Reproductive organs of the Mare.

shortly by the placenta. Due to the mild form of placental attachment, only the surface epithelium is lost and the mare's uterus can be ready to accept a new embryo and start a new pregnancy as soon as 15 days after parturition. Because the source of progesterone was discarded at birth (placenta), LH can be released to mature follicles, which cause estrus as soon as 2 to 11 days (average of 9) after parturition. This estrus is commonly called foal heat.

CONTROLLING THE ESTROUS CYCLE

DAYLIGHT LENGTH

The greatest problem with the estrous cycle is getting the anestrus mare to cycle early in the year. Daylight length, and to a lesser extent warmth and nutrition, are the only practical ways to get a mare to come out of winter anestrus. For light to work on the mare, the following conditions must be met:

1. Before lengthening daylight will work, she must have a period of decreasing light similiar to what normally occurs in the fall.

2. The mare must be put under a light program 60 days before the expected breeding date and must not be removed for any reason. Seventy-two hours without the light program will set the breeder back to day 1.

3. The mare needs sufficient light—it takes a 200 watt bulb, incandescent or fluorescent, for a 12 foot by 12 foot stall for 16 hours each day. Because of the overcast weather in Ohio, at least some of the artificial light should be provided in the morning to awaken the mare's system. A new method that works well is to turn on the lights for 1 to 2 hours between 1 a.m. and 4 a.m. and then turn them off. Do not give 24 hours of light each day because that is the same as not giving any light. The mare needs a light and a dark period for a lighting program to work.

4. Prolonged weather below 0° F will override the light effect; thus, it may be necessary to stable mares in warmer quarters if weather is very cold for several days.

5. Mares need to be fed adequately and in good health for breeding.

6. If a pregnant mare foals early and you wish to rebreed early, she should be under lights the same as the open mare you want to breed early.

HORMONAL CONTROL OF THE ESTROUS CYCLE

Progesterone — A major problem in breeding mares early is to establish a normal cycle as the mare comes out of winter anestrous. Most mares are in estrus for as long as 14 to 30 days during the first cycle. They usually produce multiple follicles but are unable to ovulate one and form a CL. Once they accomplish the first ovulation, they usually fall into a more normal cycle of 21 days with an estrus of 3 to 5 days and ovulation occurring 24 to 48 hours before the end of estrus.

If a mare has multiple follicles of 20mm or larger, progesterone treatment for 12 to 14 days will stop the mare from showing heat. After stopping the treatment the mare will come into a normal heat in 3 to 8 days and will usually ovulate. The progesterone most commonly used is Regumate (altrenogest), given orally to the mare each day.

The same progesterone compound has been used to keep a show mare out of heat to avoid the poor disposition of some mares when they are in heat. The treatment has been maintained as long as 90 days with no noticeable side effects.

Regumate also has been used to synchronize estrus in a group of mares so they can all be bred in a short time and foal at about the same time. Normally cycling mares should be put on regumate for 19 days and upon withdrawal should be in heat within 3 to 8 days.

Prostaglandin — This hormone is used to lyse a CL, or as long as the CL is at least 5 days old. Prostaglandin has no effect on the newly developing CL. There are three cases in which it is advantageous to eliminate a CL. The first is to short cycle a mare that either missed breeding before she ovulated or was not physically ready to be bred. An example is a foal heat mare whose uterus was not ready for a new pregnancy at ovulation time. The sixth day or later after ovulation, the mare can be treated with prostaglandin as an intramuscular shot. She will be back in heat in 2 to 8 days and will ovulate in 7 to 12 days.

The second case is to synchronize mares to breed at the same time. Two treatments usually are required because at the first treatment some mares are between ovulation and the sixth day. Therefore, two treatment are given 18 days apart and all mares will come in heat 2 to 8 days after the second treatment.

The third case for prostaglandin treatment is the pseudopregnant mare. Occasionaly a mare conceives but loses the embryo early in gestation. If the placenta has produced endometrial cups, they will persist after the death of the embryo and prevent the mare from recycling. Prostaglandin will lyse the CL of pregnancy and accessory CLs and bring her back into heat.

Human chorionic gonadotrophin (HCG) — This hormone is used to cause ovulation. If a mare has a follicle of over 25mm, ovulation should occur 24 to 48 hours after treatment. This treatment can be used in a mare in transitional anestrous to ovulate a persistent follicle. HCG also could be used to ovulate a follicle on Friday when she is bred to insure that she ovulates soon because she could not be bred again until Monday.

THE STALLION

TESTICLE

In the unborn foal, the testicle starts to develop in the area of the backbone. During development it moves toward the inguinal ring and into the scrotum. The testicle is large until about 30 days before birth. It then begins to shrink and is able to be pulled through the inguinal ring into the scrotum.

A cryptorchid is a horse whose testicle fails to descend into the scrotum. Cryptorchidism may be caused by a genetic fault, resulting in either incorrect growth of the cord that pulls the testicle into the scrotum or the testicle becoming dislocated in its descent through the abdomen. Cryptorchidism also is due to differential growth of the body after birth, causing the testicle to be drawn back into the abdomen. Both testicles should be descended by the time males are a year old. A testicle in the abdomen will produce testosterone, the male hormone, but cannot produce sperm. Most of these horses are aggressive, sterile if both testicles are retained and of lower fertility if one testicle is retained. Cryptorchids should not be used for breeding animals as the trait is inherited.

The stallion reaches puberty when sperm production begins at about 12 months of age. For this reason yearling stallions should be kept away from females you do not want bred. Although sperm production may begin as early as 12 months, about 35 percent of stallions still

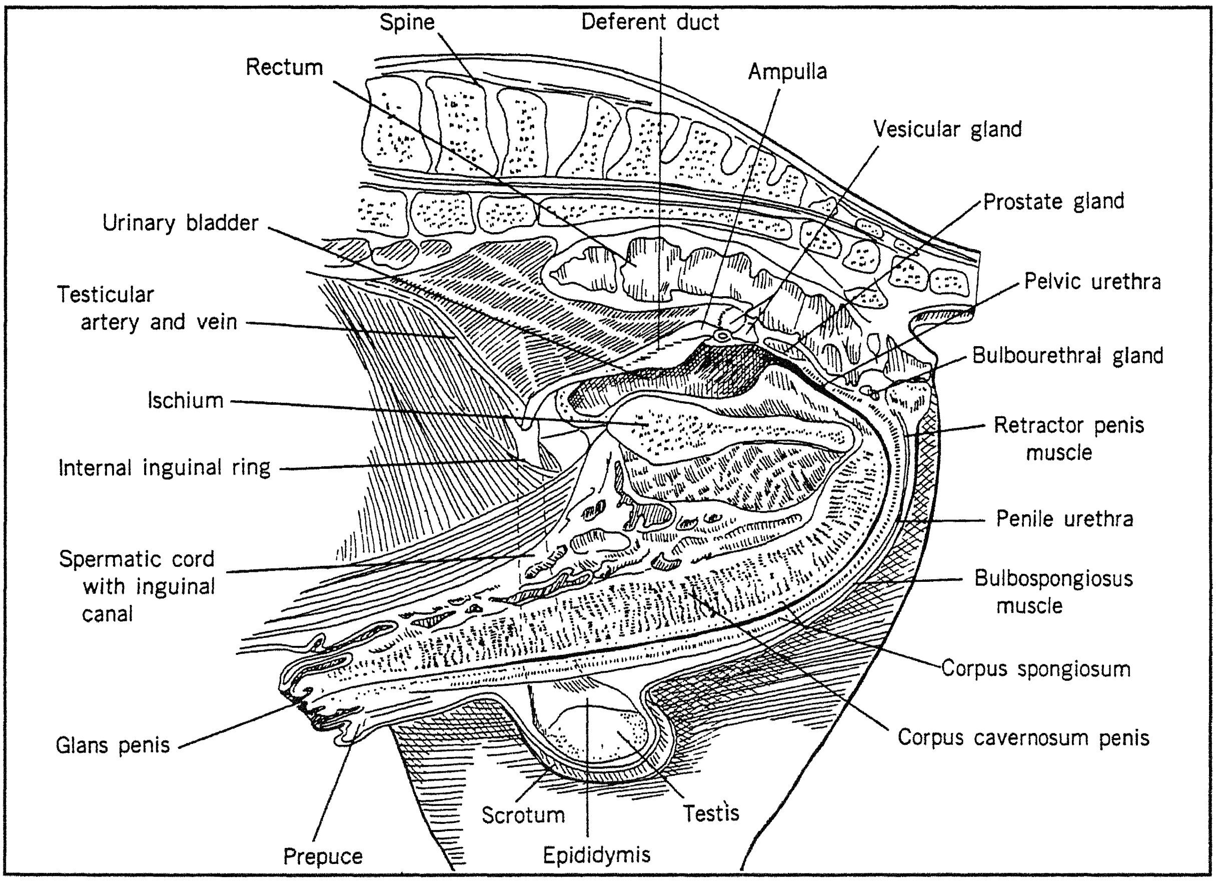


Figure 4. Drawing of the reproductive tract of the stallion as seen in a left lateral dissection. From Pickett et al.[6]1

do not produce enough sperm to settle a mare at 2 years of age. To determine if a stallion is fertile, a breeding soundness exam should be given at least 60 days before starting to breed mares. The exam also may give an idea of how many mares you can expect to breed to one stallion.

Three types of cells in the testicle are directly involved with reproduction. The testicle is a mass of tubules with connective tissue between the tubules. Within the tubules (see Figure 5), spermatogonia cells divide to produce the sperm cells. Also present are sertoli cells that nourish the developing sperm cells and produce inhibin. The inhibin probably acts on the hypothalamus to regulate FSH release, which determines the level of sperm production. The testis also produces large quantities of estrogens, which may decrease both FSH and ICSH release.

The third type of cell, the leydig cell, is in the connective tissue between the tubules. Leydig cells produce testosterone, which causes the secondary sex characteristics, maintains the function of the accessory sex glands, and are important for normal sperm production. Leydig cells are under hormonal control by ICSH (interstitial cell stimulating hormone — the equivalent of LH in the mare) from the anterior pituitary, which is controlled by the hypothalamus.

About 55 days pass from the time a spermatogonia begins to divide until the sperm is released and passes through the tubule and into the epididymis.

EPIDIDYMIS

After leaving the testes, sperm are pushed into the epididymis. This organ removes some of the fluid and concentrates the sperm. It also secretes materials to mature and nourish the sperm as they migrate from the head to the tail of the epididymis. Sperm are stored in the tail of the epididymis until ejaculated or pushed out due to more sperm being produced. Two epididymis tails can store 54 billion sperm in a normal mature stallion.

Regardless of ejaculation frequency, it takes about five days for sperm to pass from the head to the tail of the epididymis. Sperm may be stored in the tail for several weeks if not ejaculated or pushed down the tract. Sperm can remain viable for up to 60 days in the tract of the stallion.

Sperm not used in breeding are

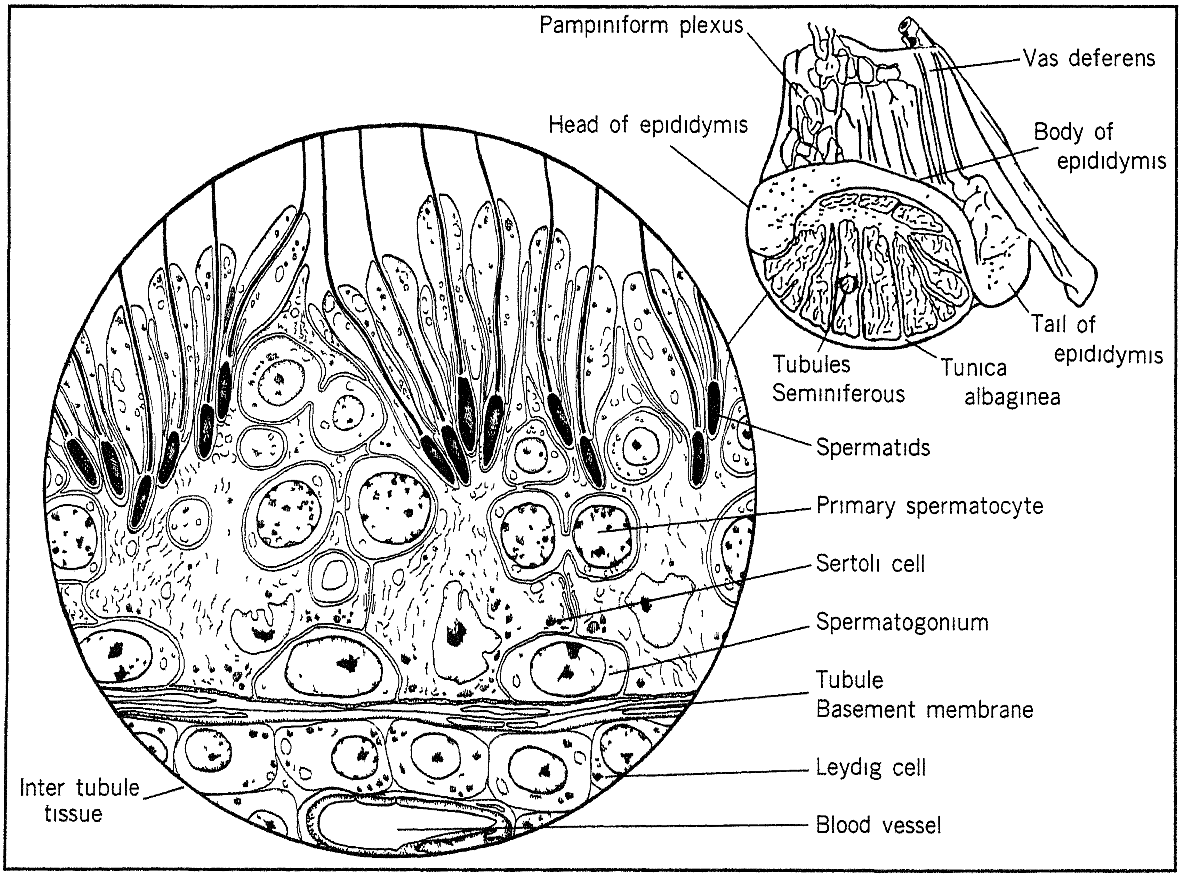


Figure 5. Equine testicle and cross section of a seminiferous tubule.

pushed down the tract and excreted with the urine, reabsorbed along the tract and/or excreted by masturbation.

VAS DEFERENS AND ACCESSORY SEX GLANDS

From the epididymis the sperm are pushed into the vas deferens, which can store an additional 36 billion sperm. Accessory sex glands are located along the vas deferens. During the ejaculation process, fluids are passed in three fractions. The first is fluid from the prostate and cowpers glands, which flushes and cleanses the ejaculatory duct. The second fraction contains sperm from the vas deferens and/or tail of the epididymis and secretions from the ampullar region of the vas deferens. The third fraction is gel-like and comes from the seminal vesicles. It pushes most of the sperm from the ejaculatory duct and has some bactericidal properties.

CASTRATION

Males of less than excellent quality usually are castrated to produce reliable animals that are more docile. The time to castrate is up to the owner. Castration can occur safely at any time in the male's life. Many breeders castrate colts as yearlings so they can be kept with fillies of the same age. Some feel a colt should be at least 2 years old to develop more massive forequarters. OSU researchers have no proof that waiting until a male is 2 years of age will help make him more massive. After castration, the horse loses most of the characteristics seen in a stallion. Castration can even be done to the old stallion that is no longer fertile or needed so he can be kept more easily on the farm or sold for a docile riding horse.

After castration the horse may still be able to settle a mare due to sperm being stored in the vas deferens above where the testicle was cut off. Theoretically he could be fertile for up to 60 days; practically he is probably no longer a threat after 30 days.

Castrated males may maintain their stallion-like behavior. Length of time depends somewhat on age at time of castration. Under 2 years of age, behavior probably will change within 30 days. Older horses, particularly if used to breed, may still want to mount mares and be stud-like longer. Most of these will change after a winter season. A few may be stud-like forever but at a much lower level of aggression. Some of these can be cured by hormone therapy.

FACTORS AFFECTING SPERM OUTPUT

Many factors have an affect on sperm production. Some of the more important are as follows:

1. Age and testicle size — The testicle grows until at least 5 years of age and often even longer. Although maximum efficiency in sperm production may occur at 2 to 4 years of age, maximum production occurs at 5 to 10 due to the larger size of testis.

In a stallion breeding exam, the total scrotal width is determined to evaluate the stallion's sperm-producing ability. A normal stallion during the breeding season should measure 96 mm plus or minus 7.5 mm for a 2 to 3 year old, 100 mm plus or minus 7.5 mm for a 4 to 6 year old, and 109 mm plus or minus 7.5 mm for stallions 7 or more years of age. Because sperm production is seasonal in the stallion, you can expect a 33 percent decrease in total scrotal width during the winter months. Some use testicle longitudinal circumference, not including the epididymus, to evaluate sperm-producing ability instead of scrotal width. Normal circumference values for light horse stallions are 27 cm or greater.

Daily sperm production in normal stallions 2 to 16 years of age should be 4 to 5 billion. Of these 3 to 4 billion are available for ejaculation. The difference between daily sperm production and daily sperm output may be due to some reabsorption along the tract but is probably more due to excretion in urine and the collector's inability to get a complete ejaculate.

2. Season effects — Sperm production in the stallion is like the normal cycling pattern of the mare. As daylight lengthens, sperm production increases. Stallions can be made to increase sperm production earlier in the year by using the same lighting programs used to make mares cycle early. If there are many mares to breed early in the year, a lighting program could be beneficial.

3. Frequency of ejaculation — The more often a stallion ejaculates, the fewer the number of sperm that will be obtained per ejaculate. Stallions should not be bred more than once a day for maximum output over a period of time. However, a stallion can be ejaculated more often each day and still be fertile. How fertile depends on the individual's ability to produce sperm and how often he is used. Most normal mature stallions could breed three times a day for a few days, but never use a 2 year old more than once per day. If this frequency

is needed often, artificial collection and insemination should be used instead. When breeding a stallion with three hours' rest between ejaculates, the second ejaculate will contain about half the number of sperm of the first. A third ejaculate taken after another three hours will have half the number of sperm of the second. Further ejaculates may not contain sufficient sperm to settle a mare—the third ejaculate would have been inadequate in some stallions.

4. Testosterone injections — Anabolic steroids have been given to horses to increase size and muscle mass. These are effective for what they are designed to do but have the side effect of producing stallions with small testis of low fertility. After withdrawal of the hormones, the stallion will be able to develop normally and probably will be fertile within six months. Mares on anabolic hormones often are infertile for 6 to 18 months after withdrawal. Testosterone also has been given to stallions to increase their sex drive, but there is no evidence that this has any effect. While HCG injections can increase libido in stallions, it is not recommended on a regular basis due to possible side effects.

5. Masturbation — Some stallions ejaculate themselves, wasting sperm. Masturbation is accomplished by rubbing the erect penis on the abdomen until ejaculation occurs. For a normal stallion with high sperm production, some masturbation probably has little effect. However, if the habit is carried to extremes or the stallion is a low sperm producer, it can have a severe affect on settling mares. Masturbation probably has an even greater effect on libido because stallions that masturbate a lot often do not display interest in a mare in heat. One way to stop masturbation is to use stallion rings, which fit on the end of the penis and prevent its enlarging. Various baskets designed to prevent the stallion from getting an erection also can be used. Stallions housed next to mares in heat or those that have mares constantly passing their stalls are more likely to masturbate than stallions housed away from mares.

6. Disease — Many diseases can cause infertility, including pseudomonas, viral arteritis, coital exanthema and fever. Most reproductive tract infections in stallions are hard to treat.

Any disease that causes a fever of more than 105° F for four hours or more can kill sperm. Because it takes about 60 days from the time sperm start to develop until it is available for ejaculation, the fever may cause a temporary sterility for as long as 60 days. Horses transported long distances occasionally have become temporarily sterile, so it is best to move stallions to their place of stud at least 60 days before the breeding season. If the stallion must be moved during the breeding season, the semen should be checked to determine if the sperm are alive. This problem is more common in draft horses than in light horses.

7. Sexual preparation — This refers to the time from when a stallion wants to breed a mare until he is allowed to mount and breed. In other livestock, particularly bulls, restraint and mounting without allowing ejaculation increased sperm output when the male was finally allowed to breed. Conflicting results have been reported in the stallion. Teasing the stallion does at least two things: 1. It increases production of the gel-like semen. This is undesirable if using artificial insemination because it plugs the insemination rod. 2. Teasing decreases the number of times a stallion will false mount before mounting and ejaculating. This is useful in artificial insemination because the fewer times a stallion enters the artificial vagina, the cleaner the ejaculate collected.

BREEDING RECOMMENDATIONS

Sperm live for 48 to 72 hours in the reproductive tract of the mare. Therefore, only one breeding every other day is necessary.

A general recommendation is not to breed more than 20 mares in a breeding season to a 2 year old stallion if using hand breeding. Hand breeding is taking the stallion to the mare in heat and separating them after copulation. Also, a 2 year old stallion should not be allowed to pasture breed by turning him out with the mares for the season. An older, mature stallion can be hand bred to 50 mares in a season if spread evenly over the season, or pasture bred to 30 mares each year. With artificial insemination (AI) these numbers can be greatly increased. Some mature stallions have been bred to as many as 400 mares in one season using artificial insemination.

STALLION BREEDING SOUNDNESS EXAM

To determine if a stallion is a sound breeder, he should be examined at least 60 days before the breeding season. This allows time to treat minor problems or to get another stallion in case this one is not fertile. The exam evaluates the stallion for general physical condition and semen quantity and quality.

Physical characteristics evaluated include anything that would prevent normal mounting and ejaculation, size and condition of reproductive organs, and the horse's desire to breed.

Measurements taken on semen quantity and quality are for volume, morphology, sperm concentration, percent live sperm, livability of sperm, reproduction tract culture and other factors such as presence of white or red blood cells. The volume of semen is variable among horses with a common range of 20 to 450 cc. The average is 120 cc, but the number of sperm is more important than the volume.

Sperm motility is the most important point of seminal evaluation. Not only do sperm need to be moving, but they need to exhibit fast linear motion across the microscopic field as they are evaluated. Ideally at least 70 percent of the sperm should be motile and show rapid linear motion. Samples with fewer than 20 percent motile sperm and slow linear motion are considered poor.

Sperm morphology is an evaluation of structure of the sperm. In general, defects are broken into primary and secondary defects. Primary defects are caused by sperm being formed incorrectly in the testes. Secondary defects are caused by sperm being stored in the stallion's reproductive tract so long that they degenerate. Primary defects are the most serious. Fewer than 10 percent primary defects is very good, and more than 30 percent is poor. Secondary defects should be fewer than 10 percent to be very good; more than 50 percent is poor. Ideally at least 70 percent of the sperm are normal.

A sperm concentration of more than 120 million sperm per cc is very good; a concentration of fewer than 30 million per cc is poor. As a mare should be bred with 500 million live sperm, the sperm concentration and total volume need to be adequate to supply at least this amount. Using artificial insemination, the normal ejaculate of a stallion collected every other day can breed 6 to 12 mares and contains 3 to 4 billion sperm.

Percentage of live sperm is determined by using a live-dead stain that stains dead cells red and leaves the cells that were alive at staining time clear. Seventy percent or higher live sperm is very good, and less than 30 percent is poor.

The culture of the reproductive tract identifies pathological organisms that make the stallion infertile. More than five white blood cells per high power microscopic field are an indication of possible infection. The presence of red blood cells indicates blood in the semen, and blood is spermicidal.

Livability of sperm in a collection bottle maintained at body temperature is good if 70 percent of those alive at collection are alive after two hours. If semen is diluted with a media to prolong life and is refrigerated, sperm may survive several days.

Artificial Insemination

This method of breeding has become more popular in the past years for the following reasons: 1. It is safer for the mare, stallion and handler if using a phantom mare. 2. It allows monitoring the quality of the semen in each ejaculate. 3. It allows better disease control because antibiotics can be added to the semen and only sterile pipettes invade the mare's vagina instead of the penis. 4. Many more mares can be bred to one stallion, increasing revenue and helping to eliminate the maintenance of mediocre or poor stallions. 5. It decreases the number of times needed to collect the semen from the stallion. You can collect semen three times a week instead of every day or many times a day.

Figure 6 depicts an artificial vagina (AV). Basically it is a cylinder lined with a hot water jacket into which the stallion ejaculates. The semen is collected into a container attached to the AV. For the AV to work, it must apply pressure to the penis. This is done with the quantity of hot water put into the water jacket.

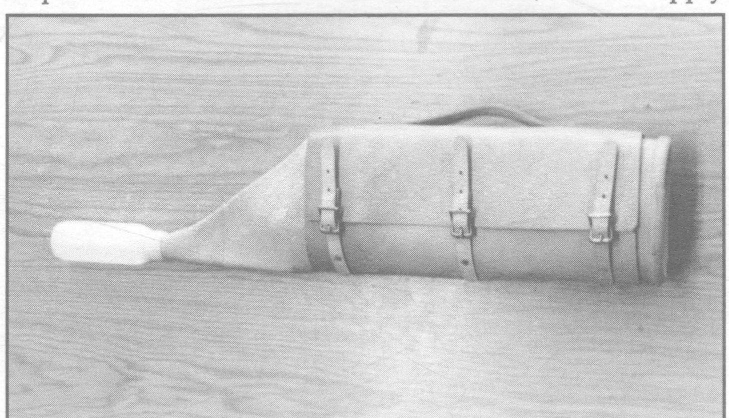


Figure 6. Artificial vagina.

The AV also must supply enough heat to the penis—about 120° F—to stimulate ejaculation. The liner is lubricated with a sterile, nonspermaticidal lubricant such as KY jelly so that the stallion's penis can enter and slide as the stallion thrusts during breeding. After the semen is collected, the AV is taken apart and thoroughly washed with hot water. Soap is not used because soap residues are hard to remove from the rubber by rinsing and will kill sperm. After it is washed, the AV is hung in a dust-free, dark area (light deteriorates rubber) to air dry. The same liner is used for only one stallion for the entire breeding season to decrease the chance of spreading infection. Disposable liners can be placed inside the regular liner.

Figures 7 and 8 show two styles of AVs, the Colorado and the Missouri models. Either will work, and each has its advantages and disadvantages. The Colorado model is excellent for maintaining temperature for long periods of time. This is advantageous for stallions that are slow to breed or in cold weather. Its disadvantages are that it is heavier and much more expensive.

The Missouri model is much cheaper and lighter to use. One disadvantage is that the water fill hole is an air valve such as you would find on an inner tube. To make it easy to fill, you can get a replacement air hose for a little hand air pump and necessary fittings to attach it to a hose that will fit your faucet.

Although artificial insemination (AI) offers many advantages, it also has some important disadvantages. The greatest disadvantage is that AI requires the semen handler to know how to collect and maintain a viable ejaculate. Sperm must be protected from rapid temperature change and exposure to much light. If a collection is being made in cold weather, the semen in the collection bottle must be protected. Figure 7 shows an insulated bag that can be placed over the end of the AV for such purposes. After collection the semen should be placed in an area such as a water bath at the horse's body temperature (100° F) until use. At this temperature semen will lose about 30 percent of its viable sperm within two hours. Therefore, mares should be ready to breed as soon as possible after collecting the stallion. Semen can be maintained longer by adding a diluent, warmed to semen temperature, to the collection bottle immediately after it is collected.

A semen diluent is a combination of substances that nourish and protect the sperm. Generally a diluent contains a sugar (usually glucose) to provide energy for the sperm; skim milk or egg yolk to protect the sperm against cold shock, buffer the toxic products of sperm metabolism and maintain proper osmotic balance; and antibiotics to destroy bacteria in the

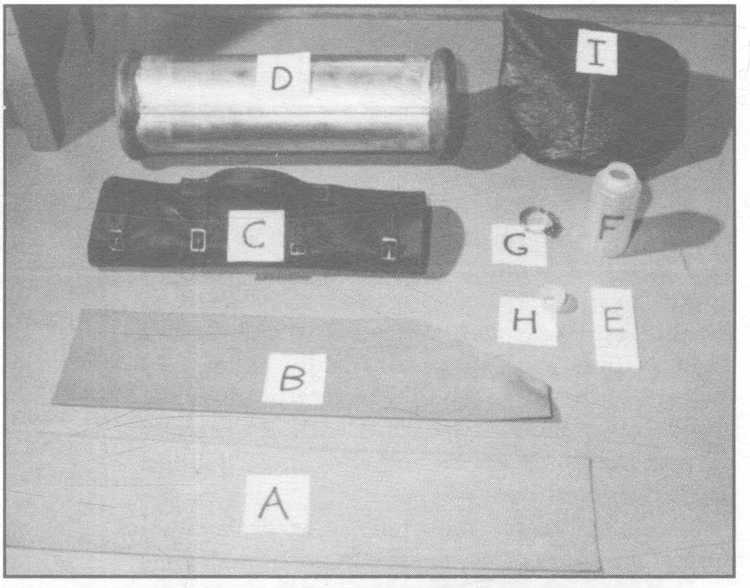


Figure 7. Colorado Model of A.V.
Liner (A) goes inside (D) and folds over the ends to form the water jacket. Place (B) inside (A). The semen filter (E) is held inside the collection bottle (F) by the Hollow stopper (H). Use clamp (G) to hold the collection bottle to the taped end of liner (B). The cover (C) on (D) will provide an easy way to handle the A.V. Use the insulated bag (I) at the end of the A.V. to maintain warmth.

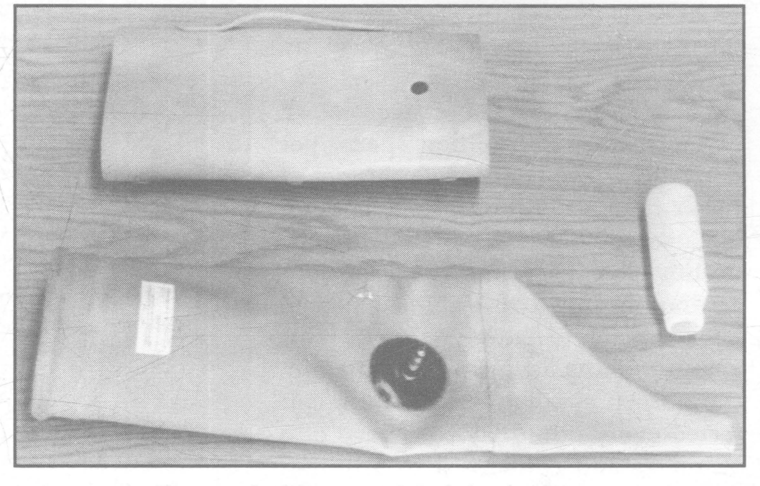


Figure 8. Missouri Model of A.V.
A. Double wall liner — water goes between liners
B. Leather cover to hold liner
C. Collection bottle — filter may be added and then bottle may be taped or clamped to liner (A). Also have disposable plastic collection bags available to attach to end of liner instead of bottle.

ejaculate. Commercial diluents are available if desired.

A second disadvantage of AI is that it requires more equipment. In addition to the normal supplies for breeding, it takes an AV, a microscope, water bath and/or incubator to keep equipment and semen warm, and clean storage space for the equipment are needed. A phantom mare is preferred to a live mare because collections can be made more safely.

Getting a horse to breed an AV if you also allow him to breed naturally is another disadvantage of AI. If you plan to use AI, always collect the stallion in an AV during that breeding season. Some stallions breed either way, but many will not. In general, if you plan to breed 30 or fewer mares to a stallion in a breeding season, you should not need to use AI unless you have a stallion with low fertility or a disease problem.

TRAINING THE STALLION TO BREED THE PHANTOM

A phantom mare is a mounting dummy built strong enough for a stallion to mount and be artificially collected. Figure 9 shows a homemade phantom that consists of old telephone poles held together with steel straps and butted against a wall to prevent the stallion from pushing it down. A 6-inch layer of high density foam (bought from a mattress company) is covered with a nylon reinforced, rubberized tarpaulin made by a local canvas company.

Some factory-made dummies use steel beams instead of the telephone poles and the rest is of similar materials. The factory-made phantom usually has the advantage of height adjustability for different-size stallions.

In general, the phantom's height should be about 4 inches less than the stallion. If it is too low, the stallion may crawl too far up on the phantom and bump his stifles on the end. If the phantom is too tall, he may have trouble staying on during ejaculation.

The width of the phantom needs to be the width of a mare (about 18 inches). If it is too wide, the stallion will have a hard time mounting it. A phantom is sold into which the artificial vagina can be inserted, eliminating the need for someone to hold it during the breeding process. The problem with this is that extreme stress is placed on the penis if the stallion falls off the side of the phantom during breeding.

Training the stallion to mount a phantom usually is much easier than people expect. It is also easier for a horse that has never bred a mare. Start by putting the stallion in an area near the phantom and a mare in heat. Be sure distractions such as other horses are out of sight. Begin by teasing the mare until the stallion has an erection and wants to mount the mare. Then pull the stallion over to the phantom and let him press his chest against the end of the phantom. This will be enough to get some stallions to mount. If not, push your hand against the end of the erect penis with the stallion's chest against the phantom and he may mount. If this does not work, the next step is to put the mare directly beside the phantom. When the stallion tries to mount the mare, pull him onto the phantom instead.

Most stallions learn quickly. Just be sure the training procedure is a pleasant one for the stallion. After the first time the stallion probably will become easier to collect. If you had to start with the mare beside the phantom, move her away after a few successful collections. Eventually the mare may be eliminated for many stallions, but some will still need to tease an estrus mare to get the initial erection and then go to the phantom for collection.

TEASING

Teasing occurs when the stallion smells, touches, talks to, bites and/or licks the

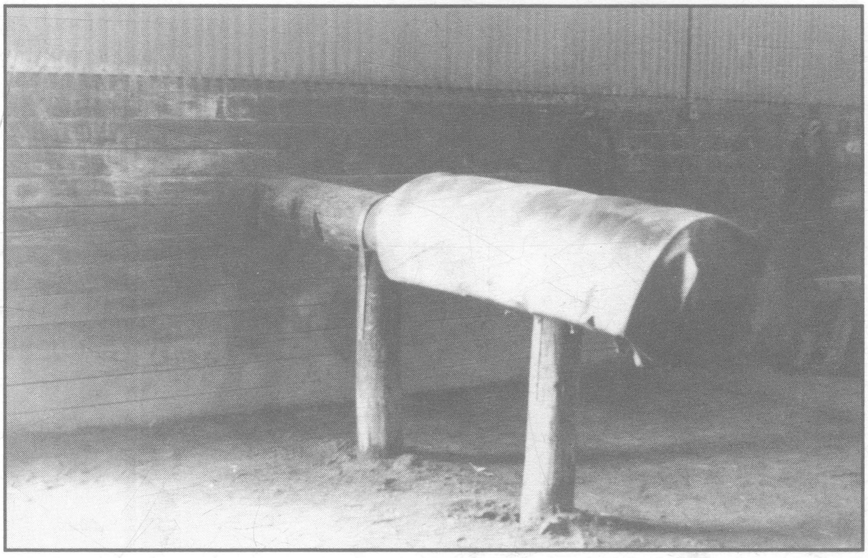


Figure 9. Phantom.

mare to determine if she will allow him to mount and breed her. Teasing is still one of the best management tools for determining estrus (sexual receptivity) in mares.

Each mare has her own type of response when she is in estrus. Signs of estrus are frequent urination followed by excessive winking (everting of the clitoris), squatting for mounting as she urinates, desire for coitus, swelling of the vulva and reddening of the membranes of the vagina, and mucous excretion from the vulva. A mare, however, may exhibit only some of these and to varying degrees.

For teasing to be most useful, it should be done by the same stallion handler every day. The handler should learn to recognize the signs of a mare coming into estrus, one ready to breed or one going out of estrus by the amount of interest she shows in the stallion.

Teasing can have detrimental effects on the stallion. If a stallion is teased every day but never ejaculates, he often becomes aggressive and may savage the mares. The mares stop showing to him out of fear and teasing is useless. A solution is to breed or artificially collect the stallion occasionally to maintain a good attitude. Stallions that bite a lot may need to be muzzled while teasing.

When teasing you may find that some mares react differently to different stallions. Many mares in foal heat will not show heat as well as they may in subsequent cycles due to a strong psychological desire to protect the newborn. Some mares will not show heat at all and other methods are necessary to determine when to breed her. Also, some mares are slower to show heat. It may take five minutes or more for mares to absorb enough stimuli from the stallion's presence before showing. If teasing is done in a group of mares, the more docile may not show because the dominant mares will chase them away.

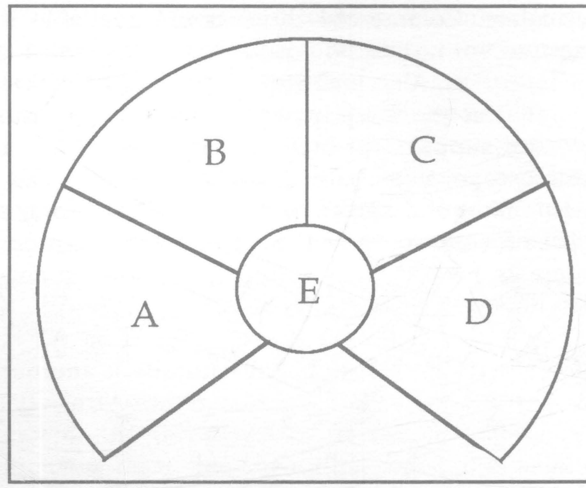


Figure 11. Teasing mill

A, B, C and D are lots of pastures that attach to E, a 60 foot round pen with stout 6 foot high walls in which the stallion is placed.

Safety during teasing is critical for all involved. During teasing the stallion may bite, strike with the front feet or kick with the rear feet, and the mare can do likewise. The handler must be alert at all times and stay out of the way of flying feet. Ideally a solid wall 4 to 5 feet tall (Figure 10) is used with one horse on each side. Other, riskier methods are teasing across gates and through partly opened stall doors. Figure 11 shows a teasing system where the stallion is placed into a pen surrounded by pens or pastures of mares. The stallion is left there for several hours, and the mares that come to his pen are recorded and checked for estrus.

For teasing to be beneficial, a daily record must be kept on each mare. Figure 12 is a sample of such a record form. The back of the form provides space for palpation and ultrasound results and for further description of treatment.

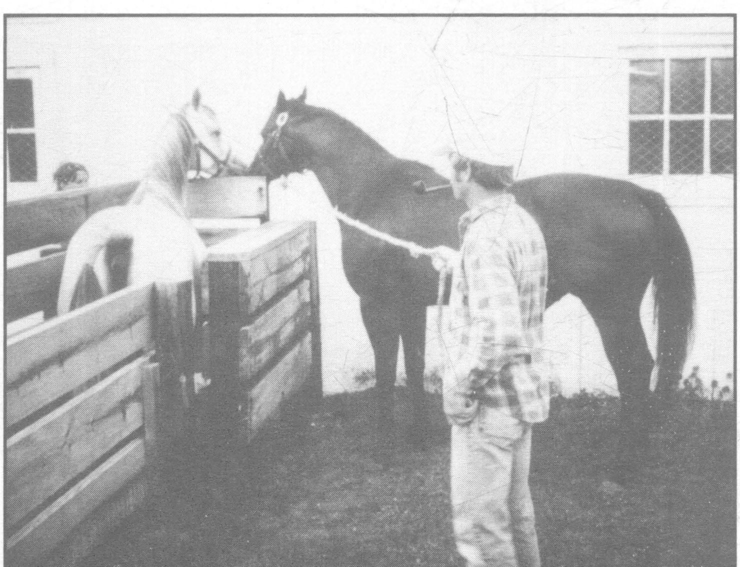


Figure 10. Teasing wall

Figure 12. Teasing Record (on 5x8 card)

Mares name ______________________ Stallion ______________________

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January																																
February																																
March																																
April																																
May																																
June																																
July																																
August																																
September																																
October																																
November																																
December																																

− Mare out of heat
−+ Mare coming into heat
\+ Mare in heat
+− Mare going out of heat

b Breed mare
B Bred mare
F Mare foaled
c Culture mare

d Cultured mare
T Treated mare

Owners name ______________________

(Front of Card)

Date	RO	LO	Uterus	Treatment and or Recommendation

(Back of card)

PREPARATION FOR BREEDING AND BREEDING PROCEDURES

Sanitation is the first consideration in preparing the mare and stallion for breeding. The mare should be washed to remove filth from any area on the hindquarters that the penis may touch when breeding. This includes the anal and vulvular area and the crease between the hindquarters down to the udder. Wash with a mild soap, rinse thorougly to remove all soap and wipe dry. Use a material such as cotton and dispose of it after washing each mare. Do not use a sponge or cloth that could carry disease from mare to mare. The mare's tail should be wrapped to prevent the dirt in the tail from getting into the vagina. Another reason is to prevent a stallion from cutting his penis on a tail hair that might be lying across the vulva as he mounts the mare. A good tail wrap that is cheap and easy to wash and reuse is an old bicycle inner tube cut and then split lengthwise. A string can be placed in one end to tie it when it is wrapped on the tail.

Before breeding, the stallion's penis should be washed with a mild soap, rinsed thoroughly (soap kills sperm) and wiped dry using a disposable material such as cotton that will not be used on another horse. Research has shown that washing the penis is good, but excessive washing with powerful disinfecting soaps can be harmful. Stallions washed with these soaps have more infections and are more likely to spread infection than those washed with plain water. This is because the stronger soaps kill the normal nonpathological bacteria that prevent dangerous bacteria from growing.

Restraint during natural breeding may be needed for the safety of handlers and horses. Breeding hobbles to prevent the mare from kicking the stallion are sometimes used. These consist of a leather strap around the neck with a rope leading to straps on each of the mare's hocks. The only danger is that a stallion could fall off the mare and get tangled in the hobbles. For safety a quick release should be at the front near the handler. Some use a twitch as restraint for a mare that may kick. Most mares in heat will stand if the stallion is not savage while breeding and if she has been teased before being mounted. The only truly safe way to breed a nasty mare is to use AI.

Stallions must be trained to be gentle during the breeding act. When a stallion breeds for the first time, the handler may need to accept some bad manners to avoid damaging the stallion's desire to breed. Soon, however, the handler should require better behavior of the stallion. A stallion should not mount until permitted. He should have an erection prior to mounting and should be willing to tease the mare until the handler lets him mount. Also, the stallion should not be allowed to charge or savage the mare during mounting. Figures 13 and 14 show two ways a chain lead may be used for restraint. A whip or breeding bridles are additional means of restraint.

When to breed the mare during estrus depends on the time of ovulation. The mare ovulates about 48 hours before the end of heat. Unless you use palpation, you cannot be sure when the end of heat will occur. The general recommendation is to breed a mare every

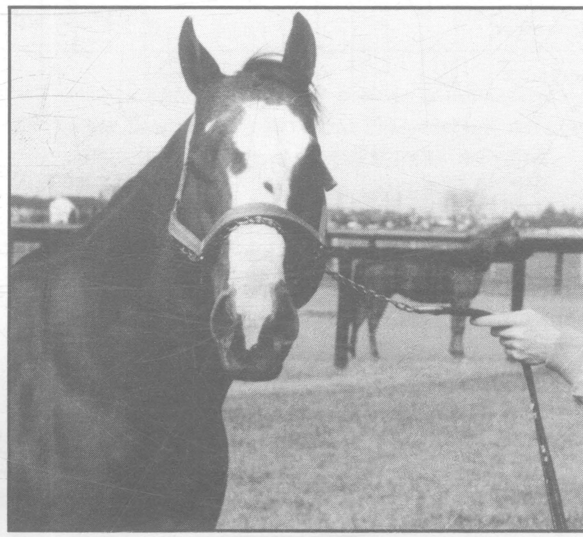


Figure 13. Chain over the nose.

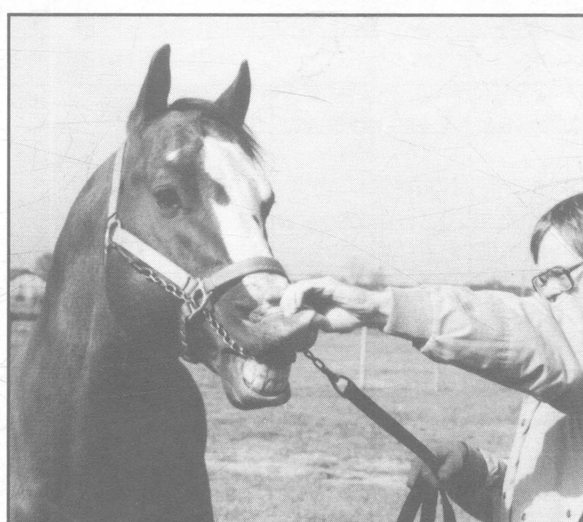


Figure 14. Chain over the gum above the front teeth for maximum control.

other day she is in heat starting on the second day. A normal estrus lasts three to five days, but early in the year it may last 30 or more days due to the transitional estrus.

Do not breed a mare more than three times per estrus because of the greater chance of infecting her. If the estrus is transitional, ovulation probably will not occur anyway. If you use teasing records and also have the mare palpated to determine the presence of follicles that will ovulate, the number of breedings often can be reduced to one or two per cycle.

FOAL HEAT BREEDING

The mare is unique because she rebreeds sooner after giving birth than any other type of livestock. This is because the placenta has a very mild form of attachment to the uterus, and the uterus can heal and be ready for a new pregnancy quickly. Research shows that the fastest the uterus can be ready to accept a new embryo is 15 days after foaling. Foal heat occurs about nine days after foaling—the normal range is 2 to 11 days. Also, fertilization of the ova occurs in the oviduct, and it takes four to six days for the fertilized ova to travel to the uterus.

The following criteria must be met if breeding on foal heat is to be successful. 1. The mare must have had a normal birth with no excessive trauma. 2. The placenta must have passed within three hours of foaling time. Retained placentas increase the bacterial infection of the uterus, slowing recovery. 3. By rectal palpation the uterus has involuted adequately. The horn that was pregnant should not be over 5 inches in diameter; the other horn should be smaller. 4. Ovulation must occur no earlier than the ninth day after foaling. Therefore, do not breed her before the ninth day.

MISCELLANEOUS MARE BREEDING PROBLEMS

Maiden mares may have a hymen, a thin membrane across the vagina, which may tear and bleed during coitus. Significant bleeding may decrease the chances of settling the mare because blood kills sperm. You can avoid this by entering the mare's vagina wearing a sterile sleeve and using sterile lubricant and tearing the hymen several days before breeding.

Older mares that have failed to foal each year may become impossible to get in foal. After age 14 a mare's uterus deteriorates quickly if she is not in foal. Therefore, keep old mares pregnant if you wish to keep raising foals. Giving her a year off may be a mistake.

Uterine infections are a problem for all mares. Maiden mares and those that foal normally and are bred using good sanitation procedures rarely have infections. If a mare does not settle after breeding for two cycles, she needs to be evaluated by a veterinarian. Usually he or she will take a culture; if the mare is old or has had a poor reproductive history, he or she will probably also do a biopsy.

A culture is done by passing a sterile rod through the cervix and swabbing the uterine wall. In the past a culture was taken during estrus, but today it is done anytime during the cycle. If you culture a pregnant mare, however, she will lose the embryo.

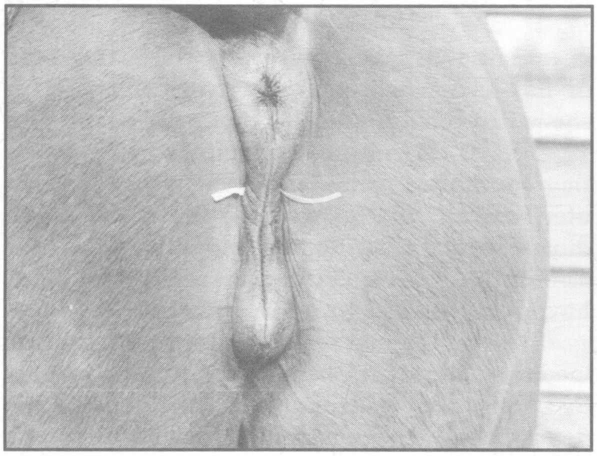
The swab is smeared on a culture media to allow any bacteria or fungus present to grow. Later the organisms are identified to determine if they are pathological. If they are, sensitivity tests are done to determine what treatment will kill the organism most effectively. Next the vet infuses the desired treatment into the mare's uterus. Uterine infections must be treated this way. Systemic treatments such as antibiotic shots are not effective. After treating the mare, the vet will wait at least a week and then reculture to determine if the treatment was successful.

The biopsy goes one step further by taking a small bite of tissue out of the uterine wall. This tissue is cultured and evaluated under the microscope for presence of scar tissue and other indications of uterine deterioration. A Grade 1 uterus is normal. Grade 2 has abnormalities, some of which are correctable by treatment. The mare has a 50 to 70 percent chance of maintaining a pregnancy. A Grade 3 uterus has irreversible conditions and has only about a 4 to 10 percent chance of carrying a foal to term.

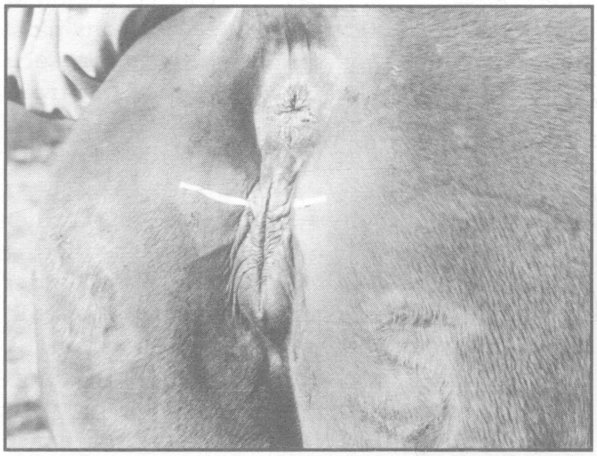
Much has been learned in the last 10 years about treating uterine infections, but early treatment is most important. The longer the infection exists, the more damage is done and the deeper into the uterine tissue it goes, making successful treatment difficult. Mares should be checked for pregnancy in the fall of the year bred to be sure they are still pregnant. Clearing up infections in the fall will prepare the mare for breeding in the spring and prevent losing valuable breeding time.

Another breeding problem is trying to breed a large stallion to a small mare. Fortunately, the horses do not usually have problems with a mare having a foal by a much larger stallion. However, at breeding time, a stallion with a long penis may tear the vagina of a small mare. To prevent this, breeders use a breeding roll often made from a wooden handle about 2 feet long and wrapped with material to make the roll 6 to 8 inches in diameter. When the stallion mounts, the roll is inserted between the stallion's belly and the mare's buttocks so he cannot enter the mare with the full length of the penis.

Good: All of opening of vulvular lips below level of pelvis, lips closed tightly, vulva perpendicular



Fair: About half of opening of vulva above pelvis level, lips closed tightly, vulvular lips slightly tilted



Poor: Almost entire opening of vulva above pelvis level, lips without normal straight closure, vulva tilts extremely forward

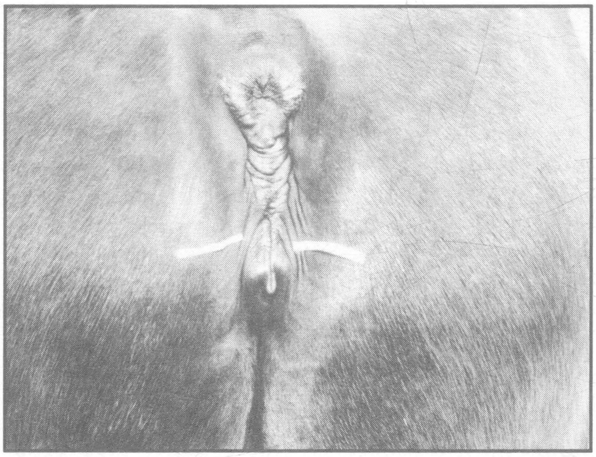


Figure 15. Vulvular conformation — Level of pelvis indicated by strips on each side of vulva.

Vulvular conformation can be a problem for a mare. Figure 15 shows three conformations. Ideally the opening of the vulva lies below the level of the pelvis. This level can be determined by using the fingers to press up and down the sides of the vulva until feeling the underlying pelvis. A vulva that is tilted forward and opens above the pelvic bone is likely to become infected from the fecal material falling across it. A caslick operation prevents infection from poor conformation. The vulvular lips are stitched together, leaving a small area at the bottom for urination. If a mare has a caslick it must be opened before foaling or the vulva will be torn badly. The vulva should be reclosed as soon as possible after foaling, leaving enough room to breed.

The conformation of the vulva worsens with age. After several foals and/or with a sway-backed condition, the vulva is pulled more forward and becomes more tilted.

Early embryonic death is common in the mare. If a mare is going to lose a pregnancy, it usually will occur within the first 60 days. Causes may be hormonal failure, infection of the uterus at time of breeding or genetic lethals. A mare should be checked several times during the first 60 days of pregnancy. Typical times to check are at days 18 to 21, 35 to 40 and 55 to 60. Mares that abort after the second check often do not come into heat for several months and will be missed by teasing. This pseudopregnancy can be maintained for several months but usually can be terminated with a shot of prostaglandin.

TECHNIQUES AND INSTRUMENTS USED IN THE BREEDING INDUSTRY

Rectal palpation is the procedure of placing the hand and arm into the mare's rectum and feeling the mare's ovaries, uterus and cervix through the rectal wall. Palpation of the ovaries determines the number and size of follicles. The corpus hemorrhagicum may be felt for the first 24 to 48 hours. Research shows that ovulation occurs in follicles at least 1 inch (2.5 cm) in diameter. A follicle may grow as large as 5 inches (10.6 cm) and still be normal. Most follicles that are about to ovulate are 1.5 to 2.5 inches (4-7 cm).

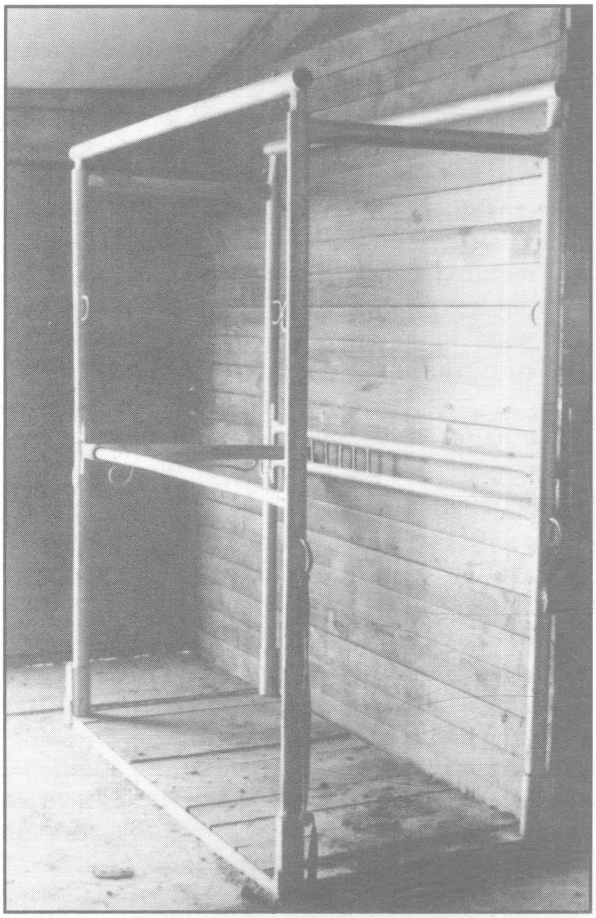


Figure 16. Homemade palpation chute.

Palpation can be used to evaluate the size and tone of the uterus. A maiden mare should have uterine horns of ¾ to 1 inch (2 to 2.5 cm) in diameter. A mare at least 30 days past foaling will have slightly larger horns than a maiden mare. A foal heat mare may have uterine horns of over 5 inches (12.5 cm). During estrus the uterine horns lose tone and grow. Uterine tone is rated excellent if the horns have a tubular structure that resists flattening as it is palpated. Excellent uterine tone is only present in the horns about 1 to 3 days after foaling and early in the pregnancy (days 18 to 40).

Uterine tone is good if horns have tubular structure and spring back to the original shape after flattening. This tone is most common during the diestrus portion of the cycle. Horns with tubular structure that do not readily return to shape after flattening are fair. Fair tone is usually a transitional phase. Poor tone is a horn that feels like an empty intestine. It is flabby, flattened and commonly found in the mare during estrus and often during anestrus. In addition to tone, a palpater may be able to feel fluid in the horns. This is common in the estrus mare that is producing a lot of mucous secretions. An abnormally enlarged and/or doughy feeling uterus or one with fluid when not in heat may indicate infection.

Palpation can evaluate the condition of the cervix. During estrus the cervix should become completely relaxed at the time of ovulation and begin to close afterward. The closed cervix during diestrus should be 1 inch (2.5 cm) wide and 2½ inches (6 to 7 cm) long. During estrus it relaxes until it can no longer be felt. From day 18 to 90 of gestation, it is narrow (½ to ¾ inches or 1 to 1.5 cm) and elongated to about 4 inches (8 to 9 cm). During anestrus the cervix may be relaxed or closed.

Palpation can diagnose pregnancy. If a mare as early as 18 days past ovulation meets all of the following criteria, she is pregnant. Follicles are no larger than 1 inch (2.5 cm), uterine tone is excellent and she has a narrow, elongated cervix. Also, by day 24 of gestation, a bulge (the conceptus) may be felt in the pregnant horn. However, only a trained palpater can diagnose the bulge this early. By day 30 the bulge is readily palpatable, and by day 45 no palpater should miss the bulge.

Palpation can be done most safely in a palpation chute (Figure 16). Only people properly trained in palpation should attempt to do so.

The use of ultrasound is probably the most useful instrument technology for equine breeding. Although these units are expensive and require professional use, they have solved many problems. Ultrasound can safely determine pregnancy as early as 16 days past breeding. With palpation, pregnancy determination has been questionable until 24 days past breeding, and most vets were not sure until 30 to 45 days. The most valuable use of ultrasound is in the determination of twin pregnancies.

Twin pregnancies are a serious economical problem in the horse (Figure 17). Most are either aborted in the last half of gestation

Figure 17. Ultrasound of twin pregnancy.

or, if born, are under-developed. About 25 percent of all ovulations are multiple. The mare has inherent ways to eliminate them. If a mare ovulates multiple follicles, the first embryo to enter the uterus from the oviduct causes both oviducts to close for 36 hours. During that time any trapped embryos at the end of the oviducts die. However, if ovulations are more than 36 hours apart, additional embryos may end up in the uterus. In some cases a mare selectively reabsorbs one of the twin embryos. With ultrasound the twin embryos can be seen at 16 days, and rectal palpation can be used to separate and crush one of the embryos. By crushing one early, before day 20, the chances of the mare retaining the other embryo are very good. Crushing an embryo much later often causes enough irritation to the uterus to reject the remaining embryo. Ultrasound has been used in mares earlier than day 16, but research at The Ohio State University has shown a significant loss of embryos if they are subjected to ultrasound examination at younger than 16 days.

Another mechanical device that has received some recommendation for estrus detection and pregnancy diagnosis is the Estron unit. This device measures the electrical conductivity of the mucous secretions near the cervix. Evaluations show that the instrument helps determine estrus or pregnancy but is not sufficient by itself to determine when to breed mares or to diagnose pregnancy.

Tests are available to determine pregnancy by chemical analysis or foaling by a water hardness analysis of the milk. Many of these tests are being evaluated for their practicality and reliability.

STALLION BREEDING CONTRACTS

Before taking a mare to be bred, the owners of both the stallion and mare should have a written contract to prevent future disagreements. Breeding contracts vary depending on each owner's risks and personal desires. The following items should be in all contracts.

1. Identification of the mare and stallion should include name, registration number and any other information needed when filling out breeding report forms.

2. Costs should be listed, including the stallion's service fee, board costs and vet expenses. When these must be paid should also be defined.

3. Most breeding farms require the mare to be healthy and in sound breeding condition. A negative Coggins test usually is required. Some contracts include a requirement for the mare to be on a vaccination program for rhinopneumonitis during pregnancy. If she is not, the owner will not have to honor any live foal guarantee. Negative uterine cultures are required by some contracts, but this is occurring less often. Most farms prefer to examine the mare upon arrival and have their vet do the cultures required.

4. Most contracts require the mare to be halter broke and reserve the right not to breed a mare if she is unacceptable to the stallion's owner.

5. The contract usually states that the stallion owner will diligently try to settle the mare, but he is not responsible if she fails to settle.

6. Most contracts make a live foal guarantee. If the mare fails to produce a live foal, the stallion owner will rebreed the mare the following breeding season for no additional stallion service fee. A live foal is defined in many ways. The most popular is a foal that can get up under his own power and nurse.

7. The method of handling the mare and her foal if she has one with her should be defined. Usually the mare owner can decide how his mare should be boarded, and it should become part of the contract. The breeding farm manager also should have a statement that says he is not responsible for injury or death of the mare and/or foal if cared for according to the contract.

8. The contract should contain an agreement of when a breeder's certificate will be given to the mare owner.

9. The names, addresses, phone numbers, date and signatures of both parties should be given on the contract.

10. Most contracts will allow acceptable substitute mares to be used if a mare dies or become infertile before she settles. If the stallion dies or becomes infertile, you may lose your money, get a refund or be able to breed to another stallion owned by the stallion owner.

Many other contractual arrangements are being used in the horse industry. Syndicates owning a stallion, those owning a mare and lease agreements for mares or stallions are but a few. A suitable contract should accompany any action to prevent misunderstandings and lawsuits.

MARE AND FOAL MANAGEMENT

BROOD MARE MANAGEMENT BEFORE FOALING

The normal gestation length in the mare is 330 days plus or minus 30. The mare does not develop much fetal mass until the seventh month of pregnancy. Therefore, she can be worked the same as a nonpregnant mare until that time. From the seventh through the ninth month, she should do only light work. Free exercise or only very light work should be done during the last months.

For nutritional care of the mare, refer to Bulletin 762, Horse Nutrition.

The mare should be in good flesh with enough fat to cover the ribs. Ideally the mare should be a little fat—not obese—at foaling time. The drain of lactation often requires more energy than the mare is fed. Excess energy stored as fat helps maintain her condition and enables her to be rebred more readily. Fat in mares does not appear to hinder mares during foaling as it does in cattle.

The pregnant mare needs to be on a good vaccination program. The foal receives antibodies through colostrum to protect him against disease. A mare should be vaccinated 30 to 60 days before foaling so the maximum level of antibodies are transferred to the foal. Do not vaccinate or deworm mares closer than 30 days because some medications may have a negative affect on the mare and/or foal at this time.

Vaccinations should include at least tetanus and flu. The mare should also have been on a rhinopneumonitis vaccination program during pregnancy to prevent abortion. The recommended vaccine, Pneumobort K, is given in the third, fifth, seventh and ninth month of pregnancy. Some recommend that it also be given between foaling and rebreeding the mare. Nonfoaling mares also should be vaccinated before breeding. Deworming helps decrease the number of parasite eggs in the manure if done 30 days before foaling. This is important because the first solids a foal eats are his mother's manure. Deworming decreases the parasite load the foal ingests.

During late gestation, a mare may be colicky because the foal lies against some part of her digestive system. Most colics correct themselves as the mare moves around. However, colics should be watched carefully and help obtained if the mare is in a lot of pain or shows more distress.

Before the mare foals, put her in a clean stall or on a pasture where she can get away from other horses. Foaling in a group of horses is hazardous, particularly if the mare has not foaled before or is low on the dominance order in the group. If chased from her foal by dominant mares, the mare will not claim her foal.

Foaling mares should be clean, particularly around the hindquarters and udder. They should also be in quiet, comfortable surroundings. Bedding should not be sawdust or shavings because they harbor the Klebsiella bacteria that may infect the foal via the navel cord or the mare's uterus.

SIGNS OF PREGNANCY AND PARTURITION

Early signs of pregnancy can best be determined by palpation and ultrasound. However, some observations made during gestation can indicate pregnancy. The most obvious is that the mare ceases to cycle. Also, a mare often has a change in disposition, usually for the better. Pregnancy seems to calm a mare and make her more careful. By seven months the rear flank should be deeper than a non-pregnant mare, but this is greatly affected by degree of fatness. Within the last 30 days the mare's belly will hang very low and often have a "V" shape to the underline. The hindquarters become flabby, the vulva elongates and the croup sinks around the tailhead as relaxin takes its effect. The udder usually begins to fill about 30 days before parturition, but this is highly variable among mares.

Waxing is often the first sign of foaling. Waxing occurs when colostrum leaks from the teats and the last drop dries on the end. Parturition should occur within 24 to 72 hours after the mare waxes. However, many mâres do not wax before foaling.

THREE STAGES OF FOALING

First stage — Uterine contractions begin and the cervix relaxes as the feet and head push against it, but there are no outward signs. The mare is restless and, if in a group, will leave the group to find a place to foal alone. This stage takes 1 to 4 hours, but the mare may prolong it due to disturbances in her environment. The first stage ends with her "breaking her water." The placenta tears open over the cervix as the foal pushes its way into the birth canal, expelling the fluid between the allantoic layer of the placenta and the amniotic layer (Figure 18).

Second stage — During this stage, the mare has strong uterine contractions, breaks out in a sweat around the neck and shoulders, and usually lies down to deliver the foal. She may get up and down several times during delivery, which may be due to her needing to reposition the foal (Figure 19). Normal delivery (Figure 20) is for the front feet to come first, soles down and with one foot slightly ahead of the other. This helps pass the shoulders through the opening in the pelvis, which is the most difficult part of the birth. If both feet are even, the shoulders may lock on the pelvis and delay or prevent birth.

Next, the nose should follow near the foal's knees; it will be covered with the amnion. As the foal is pushed out of the mare, the amnion often breaks and the foal begins to breathe. If the foal does not break the amnion, an attendant should do so immediately after the shoulders have been delivered. After the hips are delivered, the mare will probably relax with the rear legs still partly in the birth canal until the foal struggles or the mare gets up. There is no hurry for her to get up; let her rest.

The umbilical cord usually tears at this time. How soon the cord breaks is of no importance, but it must be severed after being stretched. Stretching causes the muscles in the cord to close the blood vessels, which prevents blood loss from the foal when the cord breaks. Reports that say the foal can get substantial amounts of blood from the placenta after being born and before the cord breaks are false. If the cord must be severed, first stretch the cord by holding it where it enters the body with one hand and about 4 inches from the belly with your other hand. Stretch the cord between your hands. If it does not break during stretching, it can be cut about 1 inch from the belly.

Usually the second stage takes 10 to 60 minutes to complete, with an average of 20 minutes. If 70 minutes pass, the foal will be dead. This is because the foal's placenta begins to separate from the uterus during this stage. When separation prevents an adequate supply of oxygen to the foal, he will die. Therefore, the foaling manager must recognize problems early and provide assistance quickly. A dead foal may need to be delivered by fetotomy (cutting in sections and removing).

If a mare needs help during foaling, assistance must be given with care. If you do not know what you are doing, get qualified help. If you need to place your arm into the birth canal, your arm must be clean and lubricated. An arm wedged between the pelvis and foal could be broken during a contraction. If

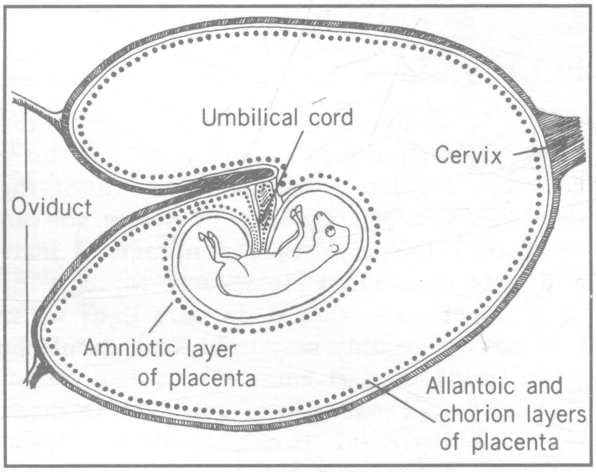


Figure 18. Uterus with fetus and its placenta.

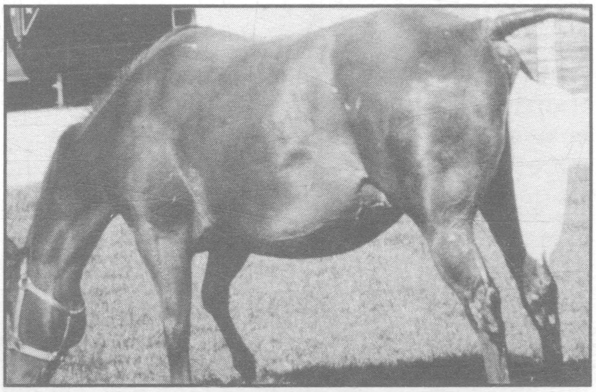


Figure 19. Mare in second stage of foaling. Amniotic sac is protruding and covers the front feet.

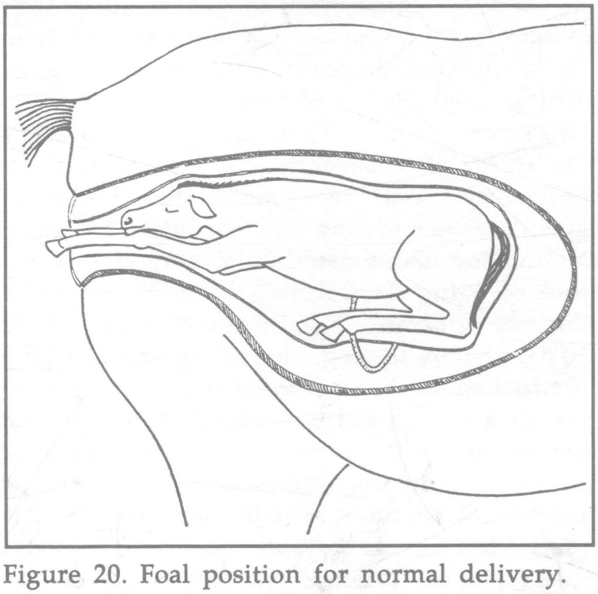


Figure 20. Foal position for normal delivery.

you pull on the foal's legs to assist birth, pull with the mare's contractions and apply no more force than two adults pulling. Usually the direction of pull should be downward toward the mare's hocks. Sometimes you need to push the foal back in a little, move one leg ahead of the other some or rotate the foal slightly to unlock it from the pelvis.

Third stage — During this stage, the mare passes the placenta. Ideally the placenta is delivered within three hours of foaling. If it is retained after eight hours, a vet needs to treat the mare.

POST-FOALING MARE PROBLEMS

Placentas retained for more than 24 hours commonly cause founder in the mare and lengthen the time until she can be rebred due to infection. After the placenta is delivered, it should be checked to ensure that all has been passed (Figure 21). There should be only one hole. Missing patches, most common at the tip of the horns, may indicate retained parts that can cause infection and founder. The placenta should never be pulled out because parts of it may remain in the uterus. Let it be expelled by its own weight and with the mare's contractions.

Foaling colic occurs in many mares after foaling (Figure 22). This colic is caused by the uterus continuing to contract painfully after the foal is delivered. The mare may lay down and roll, which could endanger the foal if she rolls violently. Foaling colic occurs within the first 30 minutes after foaling and usually corrects itself.

Excessive internal hemorrhage may occur in a mare when blood vessels break during foaling. Mares over age 14 are more likely to suffer from this problem due to the brittleness of blood vessels. Often the hemorrhage is so severe that the mare dies almost immediately. Moderate bleeding causes colic symptoms about 8 to 12 hours after foaling along with a pale membrane and a rapid heart rate. Horsemen expecting this problem may give the mare blood coagulants at foaling to try to prevent death. Today with embryo transfer, embryos from valuable old mares could be raised in young mares and eliminate the chance of death during foaling.

Turn-out of the mare and foal is critical. Exercise strengthens the foal's legs and helps return the mare's uterus to normal. During the first week, the vagina may secrete some dark exudate. However, by the second week this should stop.

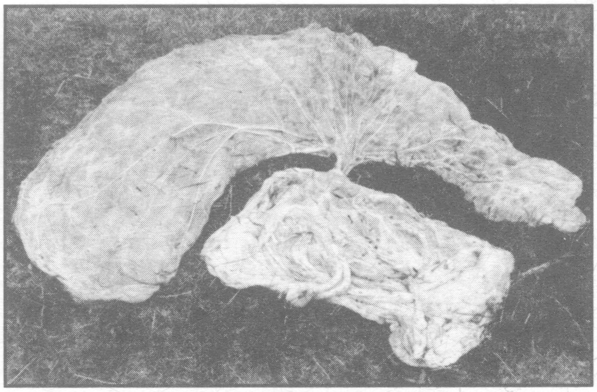


Figure 21. Expelled equine placenta. The large part at the top of the picture is the allantoic chorion. Below it is the amniotic layer. The end of the umbilical cord can be seen in the bottom center of the amniotic layer.

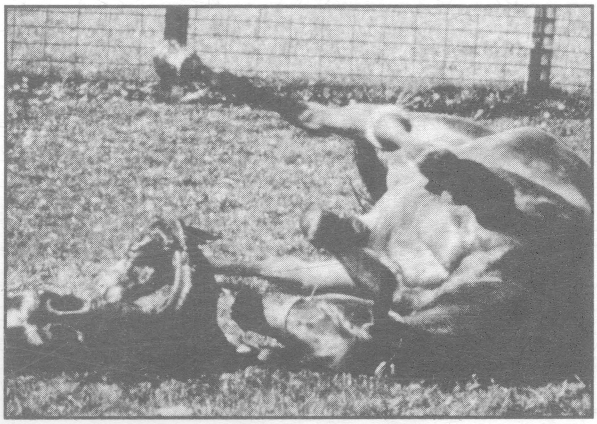


Figure 22. Mare showing typical foaling colic.

Common sense dictates when to turn out after foaling. If the weather is warm and the turn out area is clean and grassy, they could go out the first day. If they will turn out with other mares, waiting one or two days until the foal is strong may be a good idea. Do not turn out weak or sickly foals, particularly if the weather is cold or wet. Also, turning out foals in muddy lots in cold weather is an excellent way to cause foal diarrhea.

Mares with foals at their side may not show heat when teased because of their maternal instinct to protect the foal. Use palpation to determine when to rebreed these mares.

POST-FOALING FOAL PROBLEMS

Umbilical cord care after foaling has been a controversial subject over the years. Should you put iodine on the navel stump? Treating the naval is an attempt to prevent bacteria from circulating through the body via the navel. Following is a general recommendation: If you apply iodine, use a mild one. A strong iodine will cauterize the cord and seal it. Bacteria already in the cord is trapped and likely to cause problems.

After foaling, the cord seeps a little for a few days—this is nature's way of removing harmful bacteria from the cord. A mild iodine kills surface bacteria and allows the cord to seep. The only time a strong iodine is recommended is if the cord is treated immediately upon breakage and before it touches anything in the environment. Putting iodine on a foal's feet at birth has no value as there is no opening for bacteria to enter the body.

Another umbilical problem that occurs is the leakage of urine from the naval during urination. Before birth the foal excreted urine via the naval, but the tract should have closed at birth. This problem is easy to diagnose. Either you will see the navel leak during urination or you can smell your fingers after touching the cord. The problem is treated by cauterizing the cord to seal off the tract.

Nursing should occur 15 minutes to two hours after birth. When born the foal needs colostrum (first milk high in antibodies, protein and energy) to gain protection against disease. The foal's gut normally absorbs these antibodies only for the first 24 hours of life. Most foals have a natural instinct to suck, seen when the mare starts to lick the foal for the first time. A human can get the same response from the foal by rubbing the foal dry after birth.

The next problem is to get the foal to a teat. Most mares, particularly mares that have foaled before, will help the foal find the teat. Be sure the foal gets the teat in the mouth and that milk comes out of the teat. Some foals suck on the side of the udder and sound like they are getting milk. In truth they are getting nothing. Some mares have a lot of edema and the udder and belly are very sore. First-time foaling mares may not allow a foal to nurse unless you twitch or restrain her in some way. A few nursings help remove the pressure and decrease the soreness. Older, experienced mares usually allow nursing even though they are sore.

Some mares foal with no visible functional udder. Most of these develop milk almost immediately after foaling, or the vet can treat them to start producing milk if he does it within the first 24 hours after foaling. If the mare dies or does not produce milk, check Bulletin 762, Horse Nutrition, on care of orphan foals.

Foal constipation is a common problem in the newborn. During gestation the foal produced manure in the colon called meconium. This meconium is dark and often hard to expel. Shortly after birth and usually after nursing, the foal will try to pass the meconium. If the foal is constipated, an enema is in order. Probably the simplest enema is to expel about 50 cc of mineral oil gently into the rectum. Watch the foal closely to be sure one enema was sufficient. Within 24 to 36 hours, the foal should start to produce yellow manure, which comes from the milk. If the manure is yellow, the meconium has all passed.

Jaundiced foal (neonatal isoerythrolysis, hemolytic icterus) is a disease that occurs if the mare produces antibodies against the foal's blood type. The foal is born healthy, but after drinking the colostrum and absorbing the antibodies his red blood cells are destroyed and he suddenly becomes anemic. If treatment is not immediate, death follows in a few days. Treatment consists of getting the foal off the mare's milk for the first 36 hours and a transfusion of blood from a compatible donor (usually the sire if he is available). Blood tests can determine if a problem will exist before nursing begins. If the mare is milked for the first 36 hours, the foal can be returned to the mare and allowed to nurse as antibodies are no longer present or absorbable.

Combined immuno deficiency is an inherited inability of a foal to produce antibodies against disease. The foal is born healthy and remains healthy for about two weeks because the antibodies from colostrum protect him from disease. Antibiotics will be used but cannot maintain the foal and he eventually will die. The disease is a recessive trait. If the foal is affected, both parents carry the gene. Only by avoiding the use of known carriers in a breeding program can the gene be eliminated.

Leg deformities are a common problem of the newborn foal. Fortunately, most are minor and correct themselves within one to four weeks. The only deformities that require immediate attention at birth are those that prevent the foal from placing his foot flat on the ground. Casts and braces are used for these cases. If the foal can place his foot flat on the ground and after 30 days still has a major deformity, action is necessary. Because ankles stop growing by day 90 and the radius stops growing by 12 months, treatment needs to be early.

Not all problems can be corrected. Bench knees cannot be changed. However, the body will deposit more bone on the inside of the cannon and, over time, the degree of bench kneedness will lessen. Also, the splay-footed horse whose entire leg turns out will improve with age and be turned inward as the body develops. If articular surfaces are damaged, the animal may be sound for breeding, but not for work. Following is a schedule to be followed to evaluate deformities for correction:

Day 1	Look for any malformations and square off any pointed toes.
Weekly	Monitor effects of exercise and degree of change, and square off toes.
Month 1	Moderate or noncorrecting ankles require a decision as to whether ankle surgery is necessary. Check knees and trim feet in balance.
Month 2	This is the last chance for checking ankles and noncorrecting knees. Trim feet in balance.
Month 3	Ankles must be straight. This is decision month for knees, and corrective trimming should be started.
Month 4	Knee corrections must be completed. Corrective trimming continues until age 2.

Neonatal maladjustment syndrome (dummy foal) occurs in a foal that did not have an adequate oxygen supply during parturition. This usually occurs when the placenta separates from the uterus before the foal is born and is able to breathe on his own. The foal is called a dummy foal because he does not have the normal suckling desire and wanders about the stall. Some make a barking sound and are also called barker foals. The severity of the oxygen deficiency determines the chances for the foal's survival. Mildly affected foals often survive if they get milk, which may involve hand feeding for several days. If the deficiency is so severe that sufficient brain tissue decay occurs, the foal will die.

Inguinal and umbilical hernias may be found in the newborn foal. The inguinal hernia, the least common, occurs when some of the foal's intestines fall through the inguinal ring into the scrotum. This hernia requires immediate surgical correction. While the cause is unknown, excessive pressure on the foal's abdomen during birth could be a contributor.

The most common hernia is the umbilical hernia. Part of the intestine falls through the umbilical hole in the abdominal wall, making a pouch. This problem occurs in varying degrees and is rated in accordance to the size hole. Hernias no larger than one finger in diameter may close on their own by the time the foal is a yearling. Larger hernias may require clamping or surgery.

A foal with a hernia requires close management until the hernia is closed. At any time a loop of intestine could become strangled in the umbilical ring and die, causing severe colic and possible death.

Clamping has become a much-used way of closing a hernia even on those two and three fingers in diameter. Clamping a hernia requires much care to ensure that a loop of intestine is not also clamped. Put the foal to sleep and roll him over on his back to be sure all of the intestine is back inside the opening. Place a clamp around the excess skin as tight against the belly as possible; then tighten. Each day the clamp may need additional tightening. In about 10 to 21 days, the clamp drops off with the dead skin held within the clamp. The hernia closes as scar tissue forms in the umbilical area.

The umbilical hernia is most often caused by a recessive inherited trait. If a foal is born with a hernia, it means both parents are carrying the recessive gene. A hernia can be a result of excessive abdominal pressure during birth, blows to the umbilical area or forceful separation of the umbilical cord. However, if a mare or stallion commonly produces foals with hernias, genetics should be suspected.

Foal heat diarrhea is a common problem in foals. A foal often gets diarrhea at the same time the mare comes into estrus after foaling. The diarrhea lasts for about a week and may cause some soreness and hair loss around the buttocks, but it is not often debilitating. Research has been done on mare's milk composition and possible parasite infections, but no one has found a solution. Some feel that diarhhea is due to the foal starting to eat roughages. Because the foal's digestive tract is not used to roughage, the tract is irritated. After the foal has a normal microbial population to handle the roughage, the diarrhea subsides. Some companies sell products that claim to provide the microbial population (usually lactobacillus) and decrease the instance of diarrhea. However, at least one farm in Ohio using one of these preparations lost seven foals within 48 hours after using the material.

LACTATION IN THE MARE

Mare's milk has the following composition: 10.9 percent solids, 1.8 percent fat, 2.5 percent protein, 6.1 percent lactose (sugar) and .4 percent ash (mineral). The first milk, colostrum, is higher in all of these and also contains the antibodies the foal needs to fight disease. Colostrum is produced to some degree for the first day before decreasing to the values given above. Milk production in the mare is maintained by its removal from the udder. Milk let down into the duct system is a response to massaging of the udder before nursing. The amount of milk produced each day is in direct relation to the frequency and amount of milk removed.

Milk production peaks four to eight weeks after foaling. Production remains at a high level for the first three months, starts to decrease during the fourth month and drops quickly thereafter. Milk production quantities vary greatly from mare to mare. According to one study, average production for mares weighing 1000 to 1200 pounds was as follows: first month, 30.6 pounds; second month, 32.2 pounds; third month, 37.2 pounds; fourth month, 33.2 pounds; fifth month, 24.0 pounds; and sixth month, 16.5 pounds.

This data explains why foals usually do not eat much creep feed for the first two months and start to eat a lot by four months of age. If a mare is a good milker, she can provide most of the nutrition needed for the foal for the first two months. However, his size and growth needs soon surpass milk production capabilities. He has to look for more feed to supplement his milk diet. Feeding a lot of grain to mares to produce milk for foals is uneconomical, particularly after four months of lactation. It is better to wean the foal and grain feed it, and to turn the mare out to pasture to fatten up for next year's foal.

Lactation stops as withdrawal of milk stops and as intramammary pressure breaks down the secretory cells. In mares this is done most simply by removing the foal and turning the mare, out to pasture or placing her on hay. Udder disease such as mastitis is uncommon in mares, and total stoppage of milk removal works well. The udder remains tight and tender for one to two weeks after weaning and usually regresses to prelactation size in 30 to 45 days. Avoid turning weaned mares out with foals, but if it is necessary, be sure the udder is completely regressed. Otherwise a foal may nurse and lactation will be reestablished. Some feel that it is inhumane not to milk out the mare because of the tenderness associated with a tight udder. They milk the mare out on a schedule that decreases the number of milkings over several weeks. This method works but requires much more labor and time.

Many methods used to wean foals work. Some general guidelines are as follows: Wean foals in pairs or more, leave the foal in familiar surroundings and remove the mare, and be sure that the fences are adequate and safe enough to keep a fretful foal and mare apart. Watch the feed consumption of foals closely as they may not eat for a few days and then overeat, resulting in colics and ruptured stomachs.

Total separation is the most common way to wean foals. The mare is removed and taken far enough away that she cannot see or hear her foal. A second method of weaning that causes less stress is to separate the mare and foal physically but let them have sight and sound contact. No nursing is allowed. To do this, a sturdy separation must be between the mare and foal. After a few days the mare and foal will begin to pay less attention to each other. After one week of separation, the mares can be taken farther away if desired with little fuss and no detectable stress.

Weaning age is based on several conditions. First is the mare's use in your program. If she is a valuable show horse, it may be more beneficial to wean the foal at as early as a week of age. Use the method outlined in Bulletin 792, Horse Nutrition, on feeding orphan foals. You may also want to wean early so a foal does not need to be sent to a breeding farm with a mare. Your reason could be to decrease board costs or to prevent the foal from getting disease common to the breeding farm.

The second condition is the health or lactation ability of the mare. The third condition is labor, as it is usually labor-wise to wean all foals on a farm at one time.

In general, most foals in Ohio are weaned at four to six months of age. Most mares remain on pasture with their foals until fall. They are then weaned so they can gain flesh for next year and because milk production is poor. Studies have shown that foals weaned at three days, two months, four months and six months appeared equal in growth and weight. However, foals weaned at three days and two months did not have the bloom and were more potbellied than foals weaned later. If weanlings are to be sold, do not wean before four months of age. Foals weaned earlier caught up in appearance by 8 to 12 months of age. Also, all foals weaned even at four or six months of age went through a rough-looking stage about three to four weeks after weaning. If a breeder is raising foals to show in the various futurities, for appearance's sake wean either 60 days before the show or 10 days before the show. Or, do not wean until after the show.

FOAL GROWTH AND MISCELLANEOUS CARE

Foals of 1000 to 1200 pound mares weigh 100 to 120 pounds at birth and will double their weight during the first month of life. Fastest growth occurs from zero to three months of age. Growth slows slightly from four to six months, and slows more from 7 to 12 months of age. By six months of age a foal weighs 36 percent of its mature weight; and by 1 year of age it weighs 53 percent of its mature weight. Also, by six months of age a foal is 84 percent of its mature height, and by 12 months, 90 percent of its mature height. By two years of age a horse is 99 percent of its mature height. Additional growth is primarily a result of muscle development raising the thoracic cavity between the shoulder blades. This growth may continue until 5 years of age.

Sex and season also affect the size of foal at birth. Males are heavier than fillies and are born three to five days later. Foals born in January to March are lighter than April to June foals. However, it takes late foals 18 to 24 months to catch up in size to early foals.

Many breeders select for size and early development in foals. In general, if you want a fast-growing, large foal to show in a weanling futurity, use parents that produce large, fast-growing foals. Nutrition can only help a foal reach its genetic optimum size---it cannot make a giant out of a small frame. A rule-of-thumb for determining a foal's potential size is that for every 4-inch difference in size between mare and stallion, the foal will be an inch taller than the shorter parent. The mare has a greater effect on size of the foal; therefore, it is wise to use big mares to get big foals.

Additional observations estimating a foal's future appearance are as follows: The face is proportionally shorter than mature length and the cranium is proportionally larger. The croup is higher than the withers due to the lack of forehand muscle development. The horse may be 2 or older before it shows definite withers and evens up in height from hip to wither. Looking at the parents may help you decide if the foal will even up. Wait until the foal is at least 10 days old before evaluating to give him time to fill out a little. Knowing how other foals in the same family of horses developed will help you evaluate how this foal will develop.

Tail chewing is a common problem with a pen of foals, particularly when the foals are in a dry lot and do not have access to pasture. Tail chewing is a habit caused by boredom. Following are suggestions for stopping the habit: 1. Saturate the tail with Apinol, a cheap liquid antiseptic that tastes terrible and is harmless. 2. Wipe cribox paste into the tail. It lasts about two weeks.

Wood chewing is a problem attributed to teething in foals or boredom. Nearly every foal will chew wood to some degree. The best solution is to prevent boredom and to use either hardwoods for stalls and fences or to cover chewable edges with steel. Preparations are available to stop wood chewing; they have variable effectiveness.

Bugs in foals' ears are a problem in some areas. The bugs suck blood from the ears, making them sore. Trimming the hair out of the ears and then using a repellent works best. A mixture of one teaspoon of flour of sulphur (available at the drug store) in a half cup of vaseline can be rubbed in the ears and works well for several days. The same material can be used around the eyes to repel flies. Commercial fly repellents also are available.

GENETICS TERMS

What any animal becomes is a result of two factors: genetics and environment. Environment includes health care, training, nutrition and all other factors that man and nature impose on the horse. Genetics, on the other hand, includes traits passed from parents to offspring that determine how an animal can respond to the environment.

In general the mare and stallion contribute equally to a foal from a genetic standpoint. However, environmentally the mare has more influence on the foal's final makeup for the following reasons. First, the mare nourishes the foal in her uterus. This has a profound effect on foal size because the mare limits the foal's size so that she can give birth to it. An experiment crossed Shetland ponies with Shire draft horses to determine the effect of mare size on both foal and mature size. The foals of Shetland mares by Shire stallions were smaller at birth and when mature than foals of the Shire mares by Shetland stallions. Second, the mare provides nourishment for the foal after birth. Foals of mares that do not milk well are slower to grow and, if not supplemented with feed, may be stunted to some degree.

Third, the mare has more influence on disposition because she raises the foal. Most foals take a rank in dominance in a herd similar to their mothers.

HOW GENETICS WORK

The nucleus of all cells in the body contains chromosomes on which genes (the basic unit of inheritance) reside. A horse has 32 pairs of chromosomes and an undetermined number of genes. In the normal body cell, the chromosomes are aligned in pairs. The chromosomes of each pair are of similar shape and have similar locations (loci) for the same gene or a variation of the same gene. The exception is the sex chromosomes in the male. The male usually is denoted as XY (XX in the female); the Y chromosome is smaller and contains few, if any, genes.

In the sex cell (ova of female and sperm of male), the chromosome pairs are separated so that each has 32 unpaired chromosomes. At fertilization the chromosomes of the ova and the sperm unite to again form 32 pairs. The genes at the same loci of the chromosomes react to produce the traits seen in the foal.

Homozygosity—genes at a locus on each of the paired chromosomes are identical.

Heterozygosity—genes at a locus on each of the paired chromosomes are different.

Dominance—a gene's ability at a locus to override the effect of the gene at the same locus on its paired chromosome. As a result, the dominant gene is expressed and the recessive gene is present but not expressed for that trait in the animal. An example is the black and liver gene for coat color. If an animal is heterozygous, having a "B" (capital letter for dominance) and a "b" (small letter for recessive), the foal will be black. A later discussion on parrot mouth shows the possible combinations resulting from crossing parents with a dominant and recessive gene.

No dominance is also a possibility. In this case, no gene is dominant or recessive and a cross between two variations of a gene may produce a trait that is a blend of both genes.

Multiple alleles are the possible variations of a gene that can occur at the same locus on the chromosome. For example, the allele for the B gene is the b gene. Sometimes there are more than two possibilities for a locus. An example is the A gene in horses. It has four possible variations (alleles) of the A gene, A^t, A, a^t and a. In this case, they are dominant in the order given.

Epistasis—a gene at one locus affects a gene at another locus. The A gene is an example because it causes the B gene to fade the black to a bay or brown, or lets B be black.

Linked traits—traits inherited as a group. When sex cells reproduce themselves, the chromosomes intertwine and then pull apart. In doing so they often exchange parts of their strands. This exchange is called crossing over and can occur at any place along the chromosome strand. However, genes close to each other—linked genes—are less likely to separate during crossing over than genes located far apart.

Sex-linked traits—traits related to the sex of the foal. The trait is carried on the sex chromosome. The X chromosome contains many genes (some estimate 5 percent of all the genes), but the Y chromosome is almost devoid of genes. This means that a male foal is genetically more like the mare. The genes on his X chromosome came from the mare, and the genes on the X chromosome are expressed because they do not have an allele to interact with on the Y from the sire.

Sex-limited traits—traits expressed only in a certain sex. For example, a mare may carry the gene for cryptorchidism but does not show it because she has no testicles. Or a stallion contains genes for milk production but does not produce milk.

QUALITATIVE TRAITS

Qualitative traits are controlled by only one or a few genes and have different phenotypes. Phenotype is what the horse looks like as opposed to genotype, or the genetic makeup. Table 1 lists some of these traits and how they are inherited.

Because qualitative traits are controlled by one or a few pairs of genes, it is possible to determine the probability of getting a certain phenotype. In some cases the genotype can be determined as well. For example, the genetic makeup of a parrot-mouthed horse is PP or Pp. If he was mated to a normal mare who is pp, the chances of getting a parrot-mouthed foal would be as follows:

PP male x pp mare = Pp (all heterozygous and parrot-mouthed)

	P	P
p	Pp	Pp
p	Pp	Pp

Pp male x pp mare = 1/2 parrot-mouth and 1/2 normal foals

	P	p
P	PP	Pp
p	Pp	pp

If the heterozygous foals were mated, the result would be three quarters parrot mouthed foals (one homozygous, two heterozygous) and one quarter normal foals.

	P	p
p	Pp	pp
p	Pp	pp

Most detrimental traits in horses are thought to be recessive. Therefore, test matings are necessary to determine if an individual is carrying that gene. For example, a stallion of excellent quality has a dam that produced foals with umbilical hernias in the past. Before promoting and using this stallion extensively, how can you be sure he will not pass on a gene for hernia?

TABLE 1. EQUINE QUALITATIVE TRAITS

Trait	Mode of Inheritance
Parrot mouth	Dominant
Cryptorchid	Dominant (may be two genes involved)
Umbilical hernia	Recessive
Combined immunodeficiency	Recessive
Congenital contracted heels	Recessive (in either of two genes)
Congenital night blindness	Recessive
Coat colors	(See section on coat color inheritance)

First, if the dam had a hernia, she was homozygous recessive and passed the recessive gene to the stallion. The stallion has the recessive gene and will pass it to at least half of his offspring. If the dam did not have a hernia, but produced hernias in her foals, she is a heterozygote and half of her foals will at least carry the recessive gene. A progeny test on the stallion could determine the probability that he is free of the recessive gene. Table 2 gives the matings required to produce a high probability that the stallion is free of the trait. The results never prove that a stallion is free of a gene but give an indication that he probably is.

TABLE 2. NUMBERS AND KINDS OF MATINGS REQUIRED TO TEST A MALE TO DETERMINE THE PROBABILITY HE DOES NOT CARRY A RECESSIVE GENE

Kinds of Females	Probability Females are Carriers (%)	Number of Matings Required at Odds of 95/100	99/100
Homozygous recessive	100	5	7
Known heterozygote	100	11	16
Normal looking but sire and dam are known carriers	67	17	26
Normal looking but one parent is a known carrier or test mate to own daughters	50	24	35

QUANTITATIVE TRAITS

Unfortunately, only a few traits are qualitative. Most traits are quantitative, controlled by many pairs of genes interacting to produce indistinguishable gradations of phenotype. Researchers use a measurement called the heritability estimate to identify what percent of the variation in a trait is caused by genetics as opposed to what is caused by the environment. Table 3 lists heritability estimates for some traits. Even in the best possible controlled research there are still some environmental effects. As a result, different researchers have found different values. Table 3 gives a range of values for some traits.

TABLE 3. HERITABILITY ESTIMATES FOR SOME HORSE TRAITS

Traits	Heritability Estimate
Speed	45-60
Weight	30-57
Wither height	40-61
Muscling	40
Disposition	23
Pulling power	26
Points for movement	41
Length of stride	68
Intelligence	53
Fertility	10

Heritability estimates are commonly divided into traits that are highly heritable (greater than 40), moderately heritable (20 to 40) and slightly heritable (less than 20). The heritability estimate is used for at least two calculations. The first is to determine the probability that a horse will be a good breeding prospect. If a stallion is being considered for purchase as a race horse, his race record would be a good indication of whether he has genes for speed as the trait is highly heritable. On the other hand, if he is being selected for pulling power, you would want more information than his record because this trait is only moderately heritable.

In all cases, look at all records available on a horse and his close ancestors to make a purchasing decision. Table 4 shows the value records have in selecting a horse. From the table you see that the higher the heritability, the more accurate the prediction of how a horse will produce. Also, the table shows how quickly ancestor records decrease in value the more distant the ancestor.

A second use of the heritability estimate is predicting the value of the trait in the offspring. An example follows: A standardbred stallion paces a mile in 1:55 minutes and is bred to a mare that paces the mile in 2:00. The difference between the two is 5 seconds.

If speed is 50 percent heritable, the average of the offspring of this cross should pace a mile in 1:57.5 minutes (5 seconds X .50 = 2.5 seconds is due to genetics; therefore, offspring would pace at 2:00-2.5 seconds) This is only a rough estimate of value as heritability estimates are based on populations and one animal is hardly a population. If the animals in the example were from populations that had the same average speed as themselves, the answer would be accurate.

FACTORS THAT AFFECT THE RATE OF GENETIC PROGRESS

Several factors affect the rate of genetic progress in a breeding program. First is the mode of inheritance. Selecting for a trait controlled by one gene instead of many would be much easier. If you want to introduce a trait into a herd quickly, it is easier to select for a dominant trait because it is visible. However, it will be hard to get the trait in the homozygous state because its recessive gene often will be present but not seen. On the other hand, it takes longer to introduce a recessive trait into a herd because the dominant gene covers it at first. However, when the desired recessive trait is seen, it is homozygous and will produce pure.

A second factor affecting the rate of genetic progress is the generation interval. This is the time from which a foal is born until it produces a foal. The generation interval for the horse under present practices is six to eight years. This is a result of good show horses not being bred for several years due to their show use. With the advances in embryo transfer, the interval could be shortened. Show horses could produce fertilized ova without having to lose show time to produce the foal.

A third factor is the number of traits selected for at the same time. If selecting for 10 traits, progress is much slower than if selecting for only one. The solution is to start with individuals of superior quality with only one or two faults to fix instead of starting with a critically inferior horse.

A fourth factor affecting genetic progress is selection pressure. Selection pressure

Table 4. PERCENT ACCURACY OF PREDICTING GENETIC VALUE FROM OWN AND ANCESTOR RECORDS

Records Used	Heritability Level 10	25	50
	%	%	%
Own	32	50	71
Own + one parent or one progeny	35	53	73
Only one parent or progeny	16	25	35
Own + two parents	38	57	76
Only two parents	23	35	50
Own + one grandparent	32	51	71
Only one grandparent	8	12	18
Own and four grandparents	35	53	73
Only four grandparents	16	25	35

is the percent of offspring that are kept to produce the next generation of foals. The higher the selection pressure, the fewer and only the best horses are kept as replacements. Keeping only the best will speed up the genetic progress. Also, with artificial insemination it is now possible to breed one stallion to several hundred mares each year, so there is no good reason to keep any but the best stallions.

A fifth factor is the variation of genes in a population. A greater variation of genes available causes a decrease in progress simply because so many possibilities may result. Ideally a population should contain only the best expressions of a gene.

A sixth factor is records. The more records on the breeding stock, the better you can estimate the quality of the offspring. Each breeder needs to develop a record system on which to base breeding decisions. Figure 23 is an example of such a record. This is an index selection type of document. Each trait of the horse is given a weighted value and a total value is determined. The breeder culls the mares with the lowest total score. The index selection method allows for high scores in one area to make up for poor scores in other areas. Each breeder needs to determine the weight placed on each portion of the record. This should be based on the strengths and weaknesses of traits in the herd and their economic value to the breeder.

The production portion of Figure 23 allows the breeder to keep a record of the foals. This record will help in decisions on how to breed the mare based on problems identified in previous breedings. Using records of the quality of foals produced from available stallions, the breeder may decide to cull the mare even if her own record is good. B,L,Q scores are those the foal receives using the criteria from the top of the form for balance, legs and quality.

A second type of selection system is a minimum culling level. All selected traits have a required level to attain. If the horse fails in any of the traits, it is culled no matter how well it may do in the other traits.

A third selection system is called the tandem method. This system is little used because it selects for only one trait at a time. When that trait is established, selecting begins on another trait. The method produces results too slowly. If you introduced a simple dominant gene into the herd, it would take about five generations for it to be established. Five horse generations are about 40 years, or about the working lifetime of a man. A man could not live long enough to see his product if he selected for two or three traits using this selection system.

BREEDING SYSTEMS

The breeder can choose from four basic breeding systems: grading up, crossbreeding, outcrossing and inbreeding.

Grading up, the least used, is the crossing of an individual of unknown ancestry to a registered animal of some breed. The advantage of this system is that it usually produces a horse of superior quality over the scrub parent. However, starting with a scrub animal and with the goal of producing a superior animal takes too long. Also, today's horse market is for the registered animal and horses produced in this system are usually not registerable.

Crossbreeding is the mating of horses registered in different breeds. The major advantage of this system is hybrid vigor. If animals of very different gene pools are crossed, the offspring often exceeds the value of either parent.

An animal with its genes in a heterozygous state usually has more vigor.

They are often a superior looking and performing animal, but the horse also has its faults. The most critical is that the horse often fails as a breeding animal.

Ideally a good breeding animal stamps its characteristics on its offspring (prepotency). Because the crossbreed is a heterozygote, it produces offspring more like the average of the populations from which it came and the foals have great variation in type. Rarely do hybrids become a good breeding animal. Also, some breeds will not allow crossbreeding, and those that do put special registration restrictions on such animals.

Outcrossing is the third breeding system and the one most often used by purebred breeders. Outcrossing is the mating of animals from different families within the same breed. Because offspring are of the same breed, registration is not a problem. Animals also gain a degree of hybrid vigor because they are from different families.

Usually a breeder has a family of horses he wants to improve. To do this he needs to go to another family to get good traits to replace his family's defects. But be careful—if you go to several different families to get different traits, you greatly increase the possible gene variations. You may end up with an animal that contains so many gene variations that it lacks prepotency.

Inbreeding is the mating of indi-

FIGURE 23: HORSE PRODUCTION RECORD

Horse's Name	Score	Weakness
Balance 1. Symmetry (10) 2. Head and neck (15) 3. Shoulder, wither, heart (15) 4. Back, hip (15) Legs 1. Front (20)		
2. Rear (20)		
Quality 1. Sex type, refinement (10)		
2. Muscling (15)		
Disposition (20)		
Way of going (20)		
Mature height (10)		
Pedigree (30)		
TOTAL		

PRODUCTION RECORD

			B L Q Score		
Year	Sex	Sire	6 mos	1 year	Weakness

viduals more closely related than the average of the population from which they came. Linebreeding is a form of inbreeding in which a high degree of relationship to an outstanding ancestor in the pedigree is maintained. Inbreeding increases the number of genes that are in a homozygous state. This creates a prepotent animal because it decreases the gene variation an animal can produce. Offspring tend to look like the inbred parent. The problem with inbreeding is that the undesirable as well as the good genes are in a homozygous state. Breeders that inbreed should probably use a minimum culling level system and eliminate all animals with an economical genetic defect, no matter how good everything else may be.

A second problem with inbreeding is that animals with genes in a homozygous state lack vigor. Geneticists say the level of inbreeding that produces this loss of vigor is 25 percent. Most horse breeders stop when the inbreeding coefficient reaches 12 percent. Table 5 lists the kinds of matings to produce different levels of inbreeding.

TABLE 5. INBREEDING COEFFICIENTS

Relationship of Parents	Inbreeding Coefficient
Sire to daughter	25 %
Dam to son	25 %
Full brother to full sister	25 %
Half brother to half sister	12.5%
Grandsire to granddaughter	12.5%
Granddam to grandson	12.5%
Uncle to niece	12.5%
Aunt to nephew	12.5%
One common grandparent	3.1%
First cousins	6.3%
One common great grandparent	1.6%
Two common great grandparents	3.1%
Three common great grandparents	4.7%

HOW TO BE A SUCCESSFUL BREEDER

A horse breeder must have a purpose, and that purpose determines the breeding system to use. If a breeder wants to produce an outstanding performance animal, and if crossbreeding is allowed, he should choose to crossbreed or outcross. However, to crossbreed he still needs to pick horses from the different breeds that have many of the traits he would find in his ideal horse. For example, if he wants to produce a great cutting horse, he may use a king bred mare (known for cutting ability) of the quarter horse breed and cross on a thoroughbred stallion of the Three Bar line (also known for working ability).

However, if a breeder wants an outstanding horse that will be a great producing stallion or mare, a different method should be used. He should start with a few of the best mares of a breed that come close to his ideal. (It is far better to start with a few excellent related mares than 100 mediocre ones.) From these he may outcross to other families only to get one or two needed traits. When these traits are obtained, he begins to inbreed to create a high quality family. Families are important in breeding because a horse always produces offspring that are close to the average of the population from which they come. Therefore, excellent families insure excellent offspring. As the family of horses is inbred, outcrossing or crossbreeding will need to be done occasionally to maintain vigor. To accomplish this, the breeder should find a stallion that is as close to his ideal as possible but is unrelated. Crossing him on his mares will decrease the inbreeding level and produce horses less likely to produce as they look. However, by crossing the crossbred daughters back to stallions of the original family, the type and prepotency can be regained quickly.

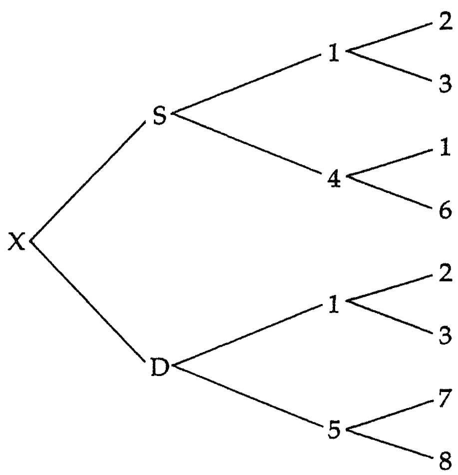
INTERPRETING PEDIGREES

A pedigree is the written ancestry of a horse. Figure 24 is an example of a pedigree that will be used in this discussion. For simplicity letters and numbers have been substituted for names. To start, each horse has a sire side of the pedigree (the upper portion, which gives the ancestors of the sire) and the dam side (the lower portion containing the dam's ancestry). By convention the sire of an individual is listed above the dam. In the example, S, 1, 2 and 7 are males and D, 3, 4, 5, 6 and 8 are females. For practical purposes no more than a five-generation pedigree is used due to the insignificant amount an ancestor farther away contributes.

The first thing a pedigree provides is the percent of an individual's genes that come from another individual in the pedigree. Usually you want to know the relationship of the product (X in the example) to any outstanding ancestors in the pedigree. This tells the probable proportion of genes X has from that ancestor. Every individual obtains half its genes from each parent. Therefore, for each generation an individual is separated from another, the genetic effect is halved. Parents contribute one half each, grandparents one fourth, great-grandparents one eighth, etc. To calculate the relationship, add all of the pathways from X to ancestor 1 in the example:

X - S - 1 $= (1/2)^2 = .2500$
X - S - 4 - 1 $= (1/2)^3 = .1250$
X - D - 1 $= (1/2)^2 = \underline{.2500}$
$.6250$ = the probable portion of X's genes that came from 1.

Figure 24 Sample Pedigree (a Four-Generation Pedigree)



A pedigree also can tell the inbreeding coefficient of a horse. The inbreeding coefficient is the percent of genes an individual has in a homozygous state above that of the average population. All horses within a population (breed) have some genes in a homozygous condition because they come from a common ancestor. These homozygous genes make a horse look like others of the breed. The inbreeding coefficient tells whether an animal will be prepotent. It also tells you if the inbreeding level is too high and will cause decreased vigor and low fertility in the offspring.

To determine if an animal is inbred, look for the first common ancestor that appears on both sides of the horse's pedigree. A horse can have more than one common ancestor. In the example, the common ancestor of X is 1. Individuals 2 and 3 are also on both sides of the pedigree but are accounted for because they are the parents of 1 in every case. Therefore, they do not count in determining common ancestors. To determine the inbreeding coefficient, connect all the possible paths from the sire to the common ancestor and back to the dam, and add these. Additional rules for making pathways are that no ancestor can occur more than once in a pathway, and any pathway is acceptable as long as it has at least one different ancestor in the pathway. Using the example, the following would be the inbreeding coefficient of X:

Connect all possible pathways from S through the common ancestor to D:

S - 1 - D $= (1/2)^2 = .2500$
S - 4 - 1 - D $= (1/2)^3 = \underline{.1250}$
pathways sum $= .3750$

Next the pathways are put into a formula that determines the inbreeding coefficient.

$$F_x = 1/2\ \Sigma\ (\ (1/2)^n\ (1 + F_a)\ )$$

F_x = the inbreeding coefficient of X
Σ = sum of all of the pathways to common ancestor(s)
n = the number of generations from sire to common ancestor and back to the dam
F_a = the inbreeding coefficient of the common ancestor. If the common ancestor is not inbred, the $(1 + F_a)$ part of the formula is eliminated. In the example there is no evidence that 1 is inbred, so assume he is not.

$F_x = 1/2\ \Sigma\ (\ (1/2)^n)$
$F_x = 1/2\ (.3750)$ from sum of pathways
$F_x = .1875$ or 18.75 % more of X's genes are in a homozygous condition than the average of the population

Computer programs are available that are designed to calculate the inbreeding coefficient.

A third calculation that can be made from a pedigree is the relationship of any two individuals. This tells the percent of duplicate genes they have because they are related by a common ancestor. The formula for this is as follows:

$$R_{sd} = \frac{\Sigma\ (\ 1/2^n\ \ (1 + F_a)\ )}{(\sqrt{1 + F_s})\ (\sqrt{1 + F_d})}$$

R_{sd} = relationship of S to D
Σ = sum of pathways
F_a = inbreeding coefficient of common ancestor. (In this example, A is not inbred.)
F_s = inbreeding coefficient of S = .25 or 25 percent is found by using formula for determining inbreeding coefficient
F_d = inbreeding coefficient of D that is not inbred

Determine pathways from S to D through the common ancestor

S - 4 - 1 - D $= (1/2)^3 = .1250$
S - 1 - D $= (1/2)^2 = \underline{.2500}$
$.3750$

$$R_{sd} = \frac{.3750}{(\sqrt{1 + .25})\,(\sqrt{1 + 0})}$$

$$R_{sd} = \frac{.3750}{\sqrt{1.25}} = \frac{.3750}{1.118} = .3354$$ or 33.54 % of S and D's genes are identical because they have 1 as a common ancestor.

COAT COLOR INHERITANCE

Specialized cells called melanocytes produce granules of melanin. Melanin determines the pigmentation of skin and hair. In the horse, two types of melanin are produced: eumelanin, a brown/black pigment, and phaeomelanin, a yellow/red pigment. Except for the dominant white horse that lacks melanocytes, all horses have these cells in the hair follicle of the skin. The size, shape and quantity of the melanin granules and their arrangement in the hair affect color. Several genes affect these characteristics of the granules. Color inheritance is not an exact science in that unexpected variations of color still occur. However, this section will relay color inheritance as far as it is known today.

THE BASIC COLOR GENES

B LOCUS

The dominant B gene represents the eumelanin pigment, which produces black. Its homozygous recessive bb produces a liver color.

Both fade when exposed to sunlight unless the horse has another gene that prevents fading. Most black horses BB or Bb are born mousey gray or black.

A LOCUS

The A gene has four possible alleles. Given in order of dominance they are A^t, A, a^t, a. The A^t causes the coloration that is seen in Przewalski's horse but is not found in the domesticated horse. The A gene causes the bay color pattern. It restricts most of the eumelanin granules to the mane, tail and lower legs. Eumelanin left in the body hair in relation to amount of phaeomelanin determines the shade of bay. The A gene does not create a bay pattern in sorrels because another gene has already restricted the eumelanin. The A gene may have an effect on the phaeomelanin, however, and be responsible for the lighter shades of sorrel. The a^t gene is recessive to the A gene, and when a^t a^t or $a^t a$ is present the B gene fades to a seal brown. If a bb gene combination is present, it fades the liver to a light seal brown. If the a^t gene is found in conjunction with a dominant D gene, it creates a red dun. The homozygous aa gene has no effect on the shade or distribution of color in the coat.

E LOCUS

This gene extends or restricts the presence of both eumelanin and phaeomelanin. When one is extended the other is restricted. Given in order of dominance, there are three different expressions of this gene: E^D, E and e.

The E^D gene allows full extension of black or liver throughout the hair coat. These colors will be nonfading if this gene is present. The horse born with this gene is born coal black if BB or Bb or very dark liver if bb. The E^D gene is epistatic to the A locus, and the genes A, a^t, will not be expressed even if present. The E gene allows normal expression of black and liver pigment, and the A locus will affect this expression. The homozygous ee will restrict the eumelanin granules (black and liver) to the eyes and skin, allowing only the phaeomelanin granules (red and yellow) to remain in the hair coat. This produces the sorrel or chestnut. Lighter sorrels are thought to have an A gene, and darker sorrels are probably homozygous aa. Although the term chestnut is often used to denote a dark sorrel, in this discussion of color inheritance sorrel and chestnut are considered the same.

GENES ELIMINATING MELANIN IN THE HAIR

G LOCUS

The gray gene in its dominant form GG or Gg causes a horse to become gray with age no matter what color it may be when born. As the foal begins to shed his foal hair, gray hairs are present. The horse grays further with each shedding until, after several years, he appears white. He is gray, not white, because his skin is dark. White horses have pink skin.

In gray horses pigment granules are gradually restricted to the skin and are not able to enter the hairshaft. Gray horses must have at least one gray parent. Those over 15 years of age are more susceptible to melanomas, or pigment tumors. Some grays do develop a sprinkling of color throughout the hair coat (flea-bitten). The genetics of this is unknown.

R LOCUS

The R gene causes the roan effect on the basic colors of horses. The roan gene is dominant; a horse must have at least one roan parent to be roan. It is possible that all roans are heterozygous Rr, and the homozygous dominant RR causes death to the embryo. The homozygous rr is all non-roan horses. The typical roan is the horse with a roan body, but the head, neck, mane, tail and lower legs are of solid color. Other genes may be involved because not all horses show the typical pattern. Some roan only in the rear flank, and some have only a few light hairs scattered over the body.

The dominant roan gene causes all other colors to roan except dominant white and gray. To tell a roan from a gray: roans are born roans, and grays are born a solid color and gray more with each shedding of the hair coat. Both roan and gray genes are possible in one horse. This horse is born looking like a roan but becomes gray all over with age.

Roans are classified by the base body color: Blacks are blue roans, bays are red roans, and sorrels or chestnuts are strawberry roans.

W LOCUS

The white gene W is found in the horse that is born white, has pink skin and has colored eyes. White horses are heterozygotes Ww because this gene in the homozygous dominant form WW is lethal to the embryo. The homozygous ww gene allows all other color genes to be expressed. The W gene is dominant to all other color genes.

GENES THAT DILUTE COLOR

Some genes cause melanin to be partly removed from the hairshaft. In the dun and palomino, the color is restricted to one side of the hairshaft. Others like the cremello have only a few melanin granules in the hairshaft.

C LOCUS

The C gene has three possible expressions: C, c^{cr} and c. The c gene may not exist in horses as it would cause a horse to be a true albino. The C gene is necessary for the expression of the eumelanin and phaeomelanin. The c^{cr} gene dilutes the red pigment (phaeomelanin). Therefore, if a c^{cr} gene is present, it dilutes the body color of a sorrel (chestnut), bay and lighter areas of a seal brown to yellow. The c^{cr} gene has no effect on black, liver and dark areas of seal brown because it does not affect the eumelanin pigment. When the genes are heterozygous C c^{cr} the result is a palomino. When the gene is homozygous c^{cr} c^{cr} it dilutes sorrels to cremello (almost white), and bays to perlino (nearly white body with points being dark to light rust-colored). Sometimes the c^{cr} gene, when heterozygous with the C gene, produces a red dun with dorsal stripe, zebra stripes and red points. To do this the a^t gene must also be present.

The C c^{cr} combination on a bay-base color changes it to a buckskin. Because the body hair is a combination of black and red hairs and the gene only fades the red color, the body color may be a clear yellow to a sooty yellow depending on the amount of black hair. Dorsal stripe and zebra stripes on the legs also are possible if the a^t gene is present.

D LOCUS

This locus is like the C locus in that it controls the amount of pigment in the hairshaft. Unlike the C locus, D dilutes both eumelanin (black) and phaeomelanin (red). The gene in the dominant form D either in homozygous or heterozygous state will dilute color. The homozygous dd is recessive and allows normal expression of color.

The effect of the D gene on chestnut is a dilution to a uniform yellow with yellowish mane and tail. If this horse had a gene for flaxen mane and tail, it would be called Isabella. A homozygous DD Isabella would be a palomino that would breed true if bred to another Isabella.

The D gene might be responsible for the color grulla, which is a uniform smoky gray. This is probably a result of the D gene on a black or seal brown. The gene's effect on liver color probably produces the brown grulla, which is a smoky light brown color.

The D gene also produces a buckskin or dun in a bay. A buckskin from this dilution almost always has a dorsal stripe and zebra stripes on the legs. Because the gene that causes these and the D gene usually are inherited together, they may be situated closely on the same chromosome and are usually inherited as a pair (linked genes).

If the D gene is present with the C gene, the result is not a double dilution but paler than normal colors.

Genes Controlling Markings and Patterns

White face markings are thought to be dominant genes: star (St), stripe (Sr), snip (Sn). Former opinion was that the chin spot (white on the lower lip) was a recessive, but that is being questioned. Other modifier genes may control the amount of white expressed. These modifier genes would cause a stripe, blaze or bald face.

White leg markings were once thought to be recessive, but today no one is sure. Each leg has genes that control its color independently. Distal spots (dark color spots) on the coronary band of the white leg may be caused by a dominant gene.

A homozygous recessive gene ff causes a flaxen mane and tail. However, the gene will be expressed only in the absence of either the dominant B or dominant E genes. A liver horse which is dominant E and with a homozygous recessive bb can have a flaxen mane and tail. A flaxen mane without flaxen tail or vice versa is rare but possible. This indicates that these are linked genes and usually are inherited together.

Tobiano is a color pattern of paints and pintos where the white crosses the top line, the head is colored and all legs are white. The gene for tobiano is dominant T. It is either TT or Tt in spotted horses and tt in solid-colored horses.

Overo is a color pattern of paints and pintos where the white rises from the belly and rarely crosses the topline and the legs are usually colored except for white markings. This pattern is a homozygous recessive (oo), and a solid-colored horse is OO or Oo genotypically. A third possible allele may exist, an Oe. If it is in the homozygous state, it causes a nearly white foal that has the lethal defect atresi coli (absence of an opening of the rectum). The nearly white paint or pinto possibly has this gene. Therefore, two horses that have a large amount of white should not be mated. Paints or pintos with glass or blue eyes also carry this gene.

Silver dappling might be caused by the S gene in either the SS or Ss state. The homozygous dominant lightens the color more than the heterozygote. The sorrel horse with SS appears to be a palomino. If the dominant gray gene is present with the SS or Ss genes, the horse grays faster than normal.

Appaloosa color patterns are caused by several genes that often depend on each other to produce the appaloosa patterns. The basic gene for appaloosa is ApAp or Apap. The homozygous recessive apap is a solid-colored horse.

One of the patterns of the appaloosa is the white blanket. This is the result of homozygous recessive wbwb genes. If a dominant Wb gene is present, the horse does not have a blanket. If the horse's genes are heterozygous, they will pass the recessive gene to half of their offspring. There is also a spotting gene that controls whether spots are on the blanket or whether the blanket is plain white. The homozygous recessive sp sp allows spots to be expressed on the blanket.

A third pattern is the leopard, which is a white body with many small spots. If the genes are homozygous dominant and modifiers are present, the leopard pattern results. If the genes are heterozygous along with the presence of modifiers, the horse has a roan blanket or overall roaning appearance. If the correct modifiers are not present, the horse is solid colored without regard to dominance or recessive nature of this gene.

Possible Color Genotypes

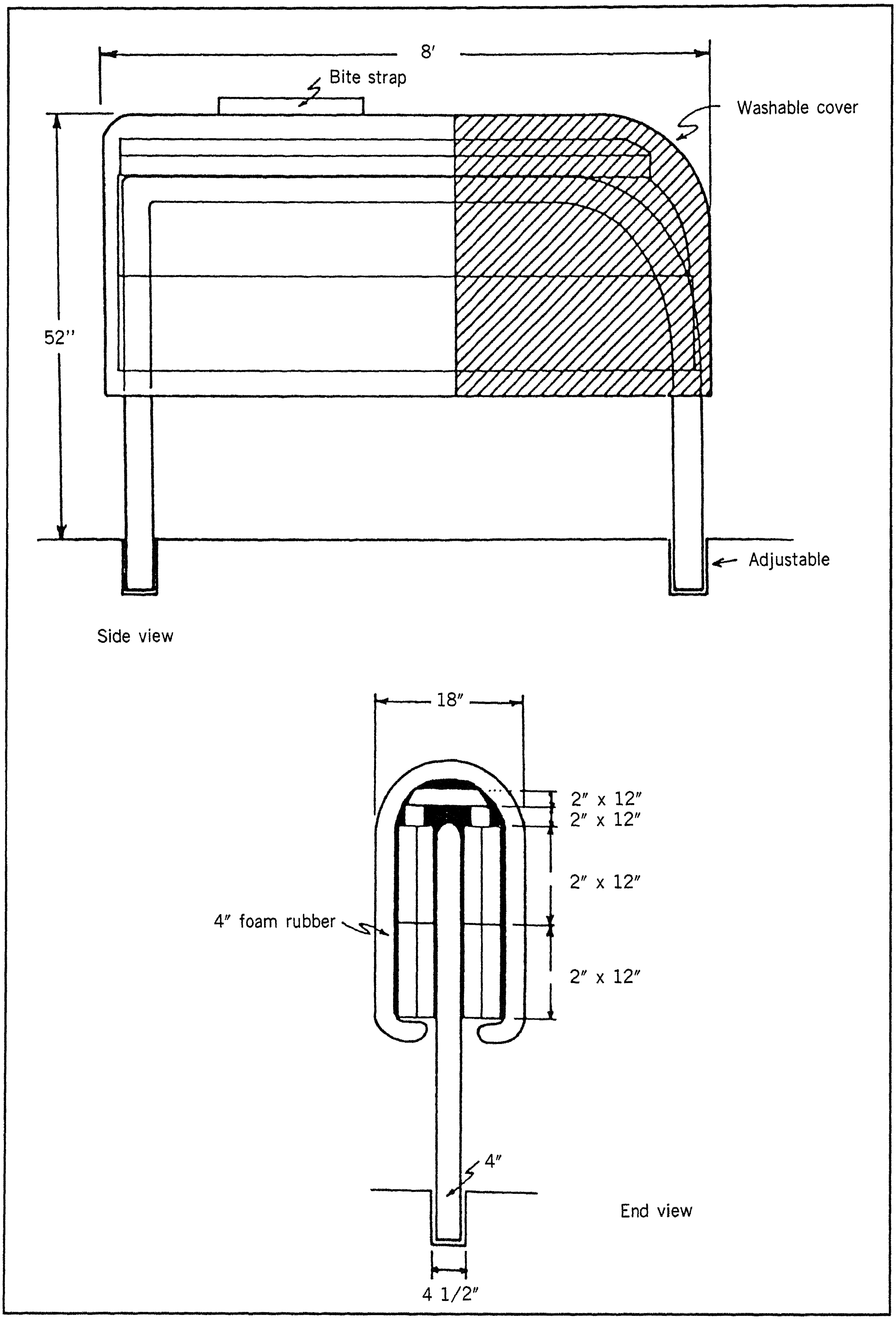
Table 6 list possible genotypes for some of the more common coat colors. Where a double blank occurs on the table, any expression of that gene could be in the blank without affecting that color. When a blank follows a letter, the blank could be filled with any expression of the gene of like or lower dominance.

TABLE 6: POSSIBLE COAT COLORS GENOTYPES

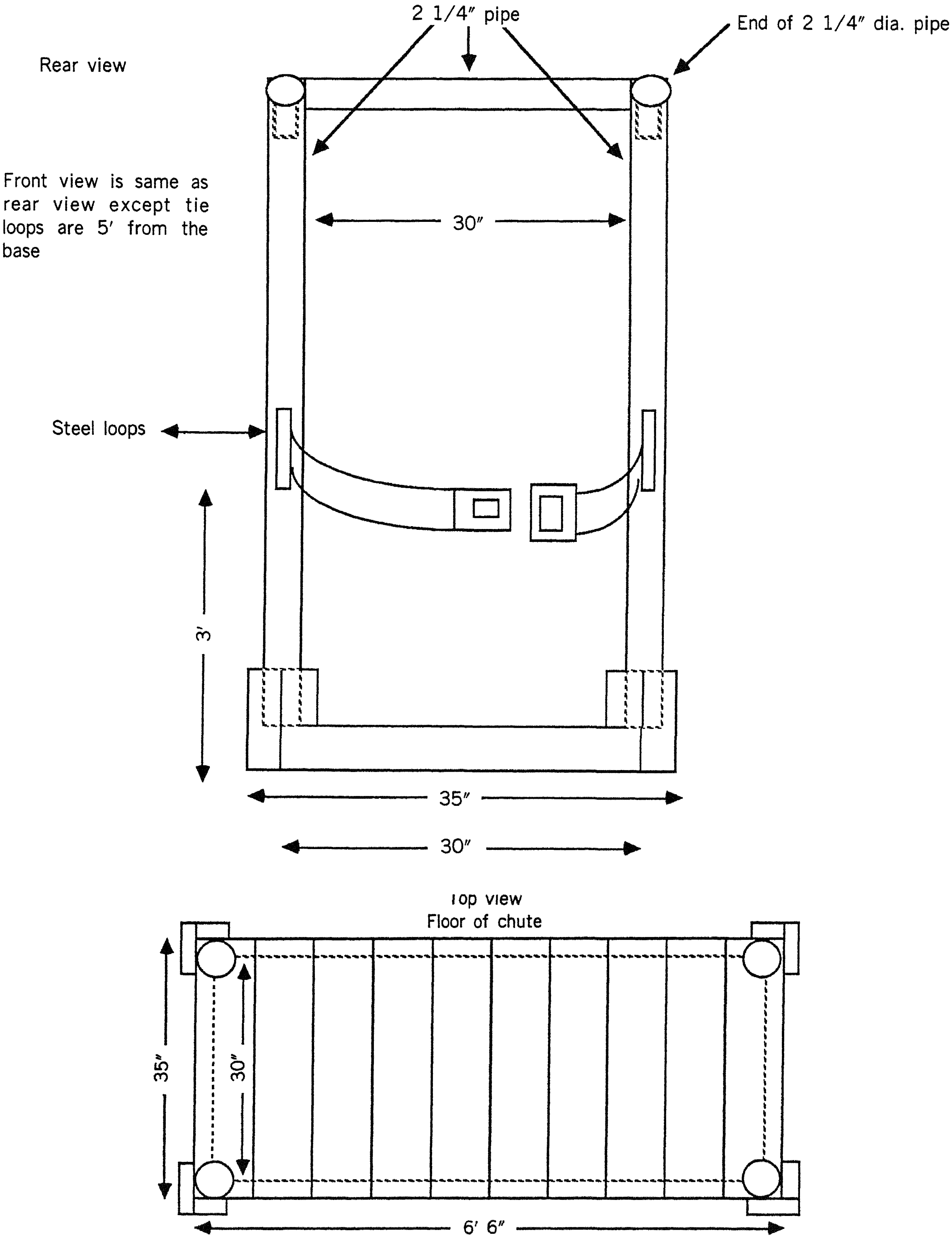
Color	B Gene	A Gene	E Gene	D Gene	C Gene
Black (non-fading)	B__	____	E^D__	dd	CC
Black (fading)	B__	aa	E__	dd	CC
Liver (non-fading)	bb	____	E^D__	dd	CC
Liver (fading)	bb	aa	EE__	dd	CC
Bay	B	A__	E__	dd	CC
Liver bay	bb	A__	E__	dd	CC
Dark seal brown	B__	a^t__	E__	dd	CC
Light seal brown	bb	a^t__	E__	dd	CC
Chestnut	__ __	aa	ee	dd	CC
Light chestnut	__ __	A__	ee	dd	CC
Palomino	__ __	__ __	ee	dd	Cc^{cr}
Palomino[1]	__	____	__ __	D__	Cc^{cr}
Pale palomino	__ __	__ __	ee	Dd	Cc^{cr}
*Buckskin	B__	A__	E__	dd	Cc^{cr}
*Buckskin	B__	A__	E__	D__	CC
*Pale buckskin	B__	A__	E__	D__	Cc^{cr}
Red dun	B__	a^t__	ee	D__	CC
Red dun	__ __	a^t__	ee	dd	Cc^{cr}
Blue grulla	B__	aa	E^D__	D__	CC
Brown grulla	bb	aa	E^D__	D__	__ _

[1] Must also have genes for flaxen mane and tail, and either the E gene or the B gene must be homozygous recessive.
* If the a^t gene is present, the horse will have a dorsal stripe.

Appendix A: Dimensions for Breeding Phantom



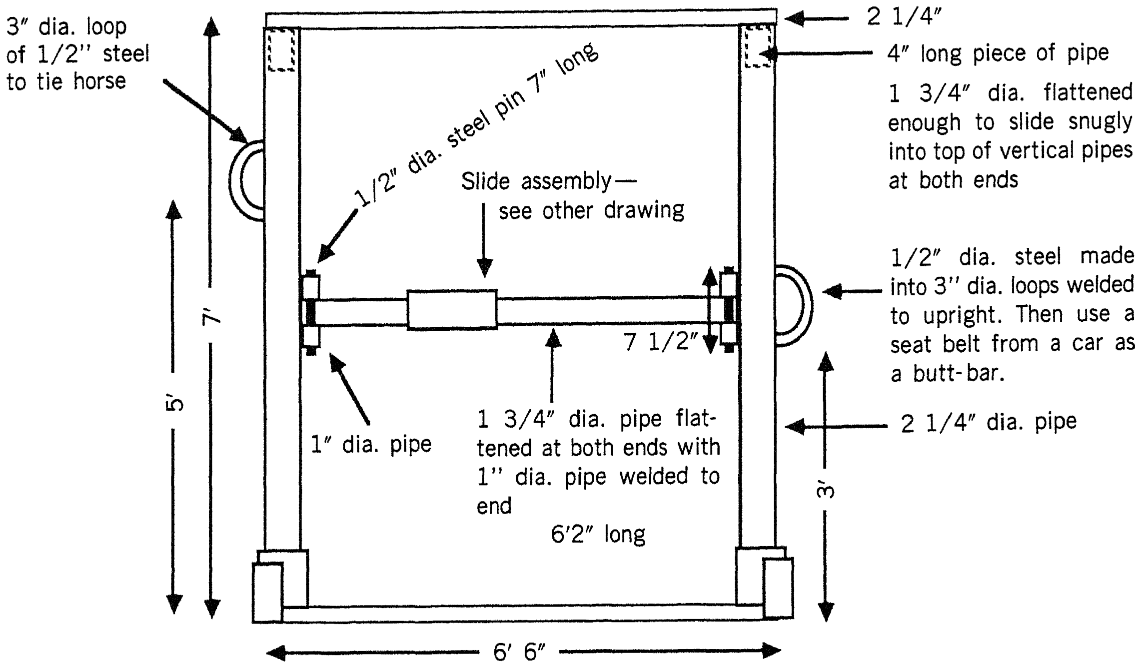
Appendix B: Plans for Portable Palpation Chute



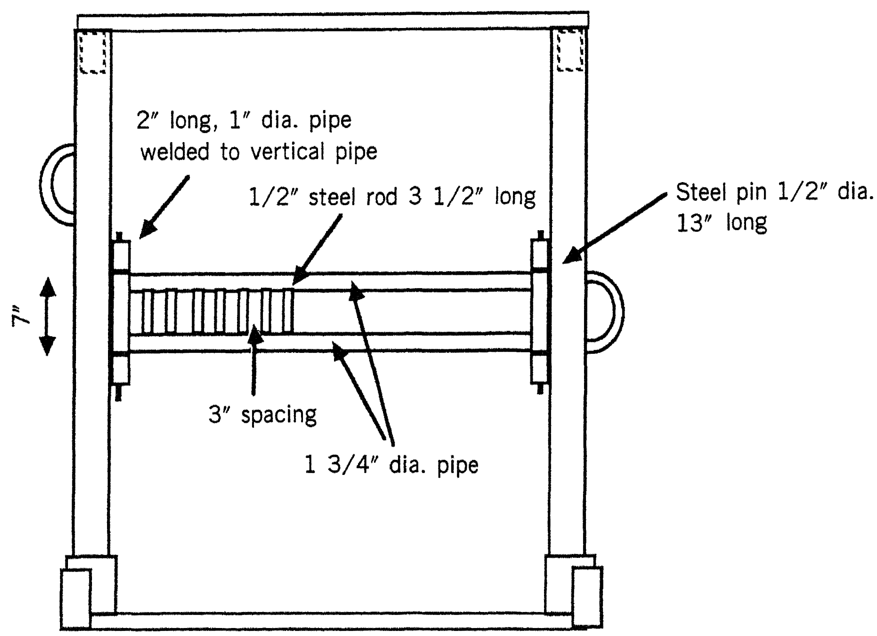
Floor has a frame made from 2" angle iron with 2" oak planks. Circles are 3" dia. (outside) pieces of pipe 8" long which are welded to the top of the angle iron of the base using 10" long pieces of 2" angle connecting pipe to itself and then to the angle iron of the base.

All pipe diameters in drawing are outside diameter.

Palpation Chute (continued)



Left side



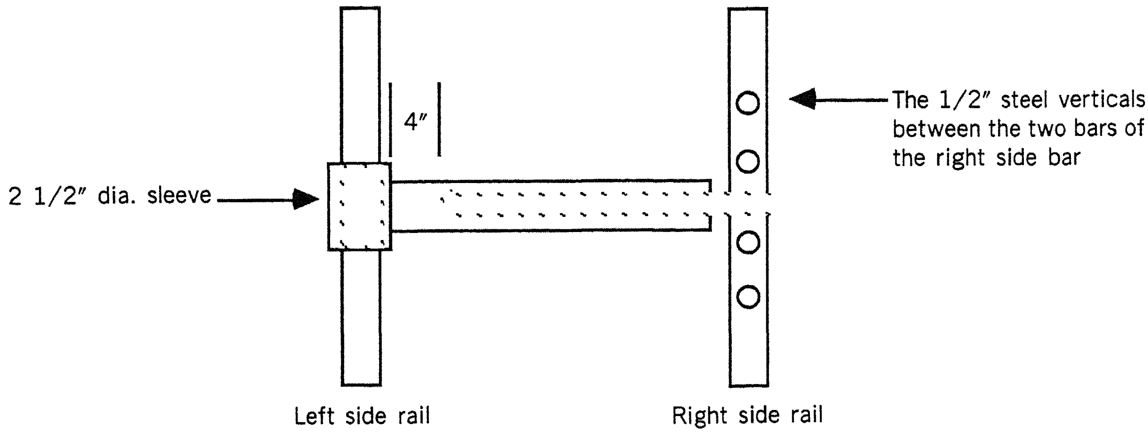
Right side

Measurements same as left side except for side bar

Palpation Chute (continued)

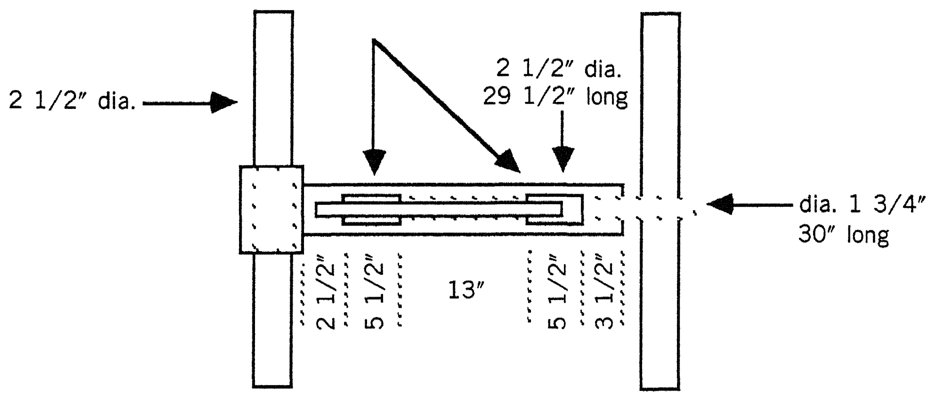
Slide mechanism

Allows for adjustment of length of chute and a way of quick release if horse jumps over the front bar.

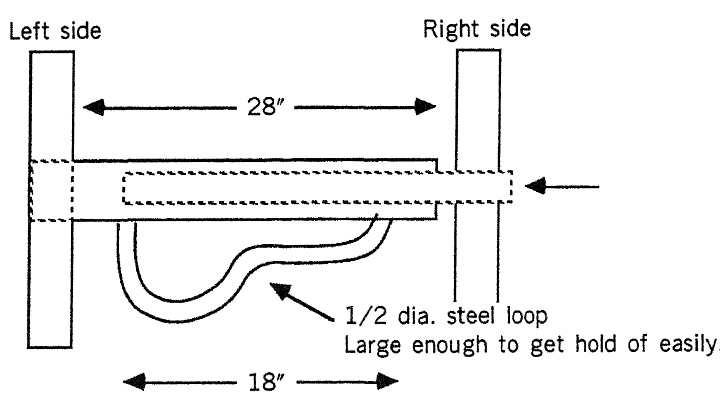


Top view

Slots cut in outside pipe 3/4″ wide so handle can move slide mechanism



Bottom view



Rear view shows slide mechanism at front of chute.

Appendix C: Addresses of Companies for Reproduction Supplies

BREEDING EQUIPMENT AND SUPPLIES

Suppliers	Items
Nasco 901 Janesville Ave. Ft. Atkinson, WI 53538	artificial vaginas, whirl-Pak bags
American Scientific Products 2340 McGaw Road Columbus, OH 43207	microscope slides and coverslips, pipettes, sperm counter, slide warmer, hemocytometer, morphology stain
Lane Manufacturing 5560 Pacific Pl. Denver, CO 80222	rubber palpation sleeves, scrotal tape, equine condoms, semen filters
Haven Lockhart Co. PO Box 390 Shawnee, KS	non-sterile plastic sleeves & boots (disposable), vaginal speculums, fuz-ez A.I. rods
Animal Reproduction Systems 9835 Dupree St. P.O. Box 3156 S. El Monte, CA	densitometer (stallion sperm counter), semen cuvettes and tops, commercially prepared diluent for semen
Johnson & Johnson 4949 W. 65th St. Chicago, IL 60600	sterile 4x4's (gauze), roll cotton
Technicare 90 Inverness Circle East Englewood, CO 80112	ultrasound machine
Monoject In. St. Louis, MO 63103	disposable plastic syringes
Bailey Wholesale Drugs 1000 Linden Ave. Zanesville, OH 43701	sterile lubricant
W. A. Butler Co. 2555 West Belt Dr. Columbus, OH 43228	non-sterile lubricant
Hamilton Equine Systems Inc. 272 Main St. Wenham, MA 01984 (617) 468-7374	sterile disposable artificial vagina liners, containers for shipping semen

Disclaimer

This is only a list of possible sources of breeding supplies and not a recommended list.